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An Air Photo Analysis of Engineering Soils

by
Donald H. Pollock
1955

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Abstract

This thesis presents a general investigation of air photo analysis as applied to glacial soils in Western Canada. Common glacial land forms, their pertinent engineering characteristics and their air photo patterns are presented and discussed in conjunction with stereopair photographs of readily identifiable land forms examples. Analyses of two test areas in the Edmonton district verified that air photo analysis coupled with limited field investigations is a most-effective method of identifying and mapping soils for engineering purposes.

#116

University of Alberta

An Air Photo Analysis of Engineering Soils

A Dissertation
Submitted to the School of Graduate Studies in
Partial Fulfillment of the Requirements for the
Degree of Master of Science

Faculty of Engineering
Department of Civil Engineering
by
Donald H. Pollock

Edmonton, Alberta
September, 1955.

Preface

Recent research in the use of air photos clearly indicates that air photo analysis may perform a key role in engineering subsurface soil investigations. Site selection programs, extensive foundation investigations, and explorations for constructional material presently necessitate costly, time-consuming field work. The completeness and accuracy of such field work is often subject to question when time and funds are limited, when areas are remote or virtually inaccessible, or when field personnel is not fully qualified. These influences are minimized and often eliminated when air photo analysis is employed prior to field work. With air photos of a suitable scale and quality, the competent analyst is able to identify and broadly outline the various subsurface soil conditions likely to be encountered in an area. On the basis of this knowledge, more suitable or more critical areas can then be noted and delineated for subsequent, concentrated field work. Furthermore, an exploration program suggesting the type, number, location and depth of test holes or test pits can be advantageously outlined. Test hole and test pit data, interpreted in conjuction with the foregoing analysis, provide a maximum amount of subsurface information from a minimum amount of field exploration.

Acknowledgments

I wish to acknowledge with sincere appreciation the encouragement and assistance given by individuals and organizations to this study.

The author is indebted to Professor R. M. Hardy, Dean of the Faculty of Engineering, Professor S. R. Sinclair, Department of Civil Engineering, and Dr. C. P. Gravenor, Department of Geology, for reading this thesis and for acting on my graduate committee. These gentlemen, familiar with problems encountered in the exploration and classification of glacial soils, have offered many valuable suggestions and comments.

I am especially grateful to Dr. J. D. Mollard, Chief of the Air Photo Analysis and Engineering Geology Division, Prairie Farm Rehabilitation Administration, for his encouragement, counsel and active assistance during the past year. Dr. Mollard is a foremost pioneer of the air photo analysis of glacial soils in Western Canada and, through his advantageous use of air photos in present-day engineering projects, was instrumental in arousing the author's interest in air photo analysis.

Acknowledgement is made to Mr. L. C. Munn, P.F.R.A. Conservationist, for his review of the final manuscript, photos and plans.

Special thanks is due to the drafting staff of the Air Photo Analysis and Engineering Geology Division, P.F.R.A.; Mr. W. E. Roberts for his excellent layout and preparation of the soils maps; Mr. R. Symyk for the preparation of the mosaics; Mr. A. B. Bouthillette for the final assembly.

I wish to thank the Photographic Division, P.F.R.A., for their preparation of the stereopair photographs which form an essential portion of this thesis.

A note of thanks is due Miss Kathy Babiuk, who typed this thesis.

The author wishes to acknowledge the source of all aerial photographs which carry the credit line: "R.C.A.F. Photo."

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Introduction

The use of air photos for determining subsurface soil conditions has originated relatively recently. Thus many engineering organizations performing field soil investigations are unaware of the significant savings in time and cost that would result from the use of air photos. A noteworthy example of the few engineering organizations using air photos in Western Canada is the Prairie Farm Rehabilitation Administration[1] where dam site selections, site foundation investigations and searches for constructional materials are greatly facilitated by the use of air photos.

It is the purpose of this thesis to present a discussion on air photo analysis and its application to subsurface soil investigation in Western Canada. The initial phase of the discussion presents common glacial land forms[2] found in Western Canada, their identifying characteristics, engineering properties, and air photo patterns. Readily identifiable land form examples selected from air photo coverage of Western Canada are included in the discussion. They illustrate various elements that identify land forms and, in addition, combine to form so-called air photo patterns.

The remainder of the report presents a qualitative appraisal of air photo analysis as applied to test areas on glacial soils of Western Canada. The area selected for a large-scale test is approximately 500 square miles located along Highway 16, west of Edmonton, Alberta. The smaller area

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[1] Headquarters at Regina, Saskatchewan.

[2] A land form is herein defined as a geomorphic unit having a particular origin and commonly having a characteristic topographic expression and physical composition.

selected for a small-scale test is eight square miles located in the Namao Airport vicinity, Edmonton. Based on an analysis of the air photo coverage, maps of anticipated subsurface soil conditions were constructed before going to the field. The results of a subsequent 4-day field trip involving spot location checks showed the nature and the amount of reconnaissance type soil information that can be derived from air photo analysis before and after field correlations. The author, who has received good training in geology and engineering soils, has no formal training in air photo analysis. He is unfamiliar with the areas being mapped, but has used both reconnaissance glacial geology and agricultural soil survey maps to assist mapping.

CHAPTER I

Principles of Air Photo Analysis

Belcher, a principal in the field of air photo analysis, has defined analysis as follows:

> "The complete analysis of an air photo, made for the purpose of determining soil conditions, is accomplished by analyzing singly, the elements of the soil pattern, weighing their importance, and combining these factors to evaluate the soil of the area in question."[1]

The elements forming the air photo pattern are visible surface features, and are a result of chemical, physical and biological processes acting on varying soil materials. The manner and extent to which these processes are manifested by the soil air photo pattern are related to the soil texture, structure, and moisture content; and thus the air photo pattern directly, or indirectly, reflects the nature of the subsurface soil condtions. The relationships between various air photo patterns and subsurface soil conditions have been compiled from the results of extensive field correlation programs.

Common air photo identifying elements are topographic expression, drainage, erosion, soil tone, vegetation and land use. Additional, but less common, elements are artificial drainage practices, erosion preventative measures, cattle trails, gravel pits and slump markings.

Air photo identifying elements of similar soils may vary from area to area according to the climatic variations. However, the regional variation of air photo patterns in Western Canada is slight; and it may be generally stated that similar air photo identifying elements in Western Canada are produced by similar subsurface soil conditions.

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1 "The Origin, Distribution, and Airphoto Identification of United States Soils," Technical Development Report, No. 52, U.S. Department of Commerce, 1946, page 76.

During the process of determining subsurface soil conditions by air photo analysis, the analyst finds it often expedient, although seldom essential, to identify and outline the various land forms encountered in an area under investigation. Each land form -- as outlined in the geological land form classification -- usually has typical subsurface soil conditions. These conditions may be characteristically uniform and defined within relatively narrow limits or, depending on the land form type, be characteristically complex incorporating rapid variations in texture and structure. Thus the analyst -- if he wishes and if he is able to identify land forms -- may use this knowledge as a basis upon which to evaluate the various elements of the air photo pattern.

The analysis should be considered complete only when the analyst is satisfied that his carefully and clearly worded account of subsurface soil conditions is entirely compatible with all the identifying elements of the soil pattern.

Air photo analysis cannot -- nor does it attempt to -- furnish the same type of information that is obtained by diligent test hole logging and laboratory classification tests.

Limitations

The amount and type of information, derived from an air photo analysis, is dependent upon the following:

(a) air photo scale, the quality and time of photography,

(b) type and distribution of land forms depicted in the photo, and,

(c) skill and experience of the analyst.

Scant data and the nature of the problem preclude a quantitative discussion on the effect of improper scale and poor quality photos. Present-day photography generally has sufficient quality to present the important microfeatures[1] of the photo pattern. On the other hand, the quality of many pre-war photos hinders present-day analysis.

Regarding the seasonal time of photography, all but the most pronounced topographic expression is masked in air photos of snow-covered land. Photography during the early spring or late fall is desired for the analysis of areas covered by heavy, deciduous-type, forest cover. The foliage is minimized at these times, and the analyst is able to view through the bared trees to the ground surface below. Soil tones are masked by heavy crops in midsummer; whereas soil tones in recently plowed fields are accentuated and constitute an important element of the air photo pattern.

A limited number of land forms such as till plains and deep lacustrine sediments were formed in relatively uniform environments. Accordingly, the subsurface soil conditions of these land forms are relatively homogeneous,

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[1] Microfeatures are considered to be those minute landscape details, visible in four inches-to-the-mile photos, that have been proven essential to the maximum utilization of air photos for the purpose of analysis.

and the analyst, when dealing with these land forms, is able to make a confident statement of the anticipated subsurface soil conditions.

Other land forms, such as eskers, kames, and some recent fluvial deposits often have a characteristic variation in texture and structure; here the analyst is obliged to outline the probable range in texture, mentioning the expected variations in subsurface soil condtions. A land form example that is complex is the floodplain of some present-day alluviating rivers. Where there are no clues to the prospective nature of the materials, the analyst can do little more than mention the complexity of horizontally stratified, interbedded lenses and laminae of most sand, silt and organic clay[1] without emphasizing the predominance of any grain size.

The inexperienced analyst usually considers topographic expression to be the basic air photo, identifying element, for he employs this element extensively in an attempt to identify each land form in an area. Upon the identification of each land form, the inexperienced analyst must infer a typical soil texture and structure as outlined under the current glacial land form classification. This classification groups land forms according to geologic origin, topographic expression, and location with respect to the ice. Thus the classification is essentially descriptive and is not entirely adaptable when used to assess soil texture and structure for engineering purposes; for the glacial drift of Western Canada, as in other areas, is relatively heterogeneous, and there is often only a broad, generalized relation between origin, topographic expression -- especially in the regional mapping levels, which is the common one -- and subsurface soil conditions. In addition, the inexperienced analyst

---

[1] "Organic clay is a clay that owes some of its significant physical properties to the presence of finely divided organic matter." Terzaghi and Peck, Soil Mechanics in Engineering Practice, John Wiley & Sons, 1948.

who is required to evaluate soil conditions in an area must necessarily identify all land forms present. It is soon realized that relatively few readily identifiable "text book" examples of glacial land forms exist in nature; that many areas do not lend themselves to land form mapping, and finally, that topographic expression alone is seldom sufficient to permit identification of land form. In fact, geological field surveys, employing intensive ground checking and subsurface drilling in glaciated areas, have often experienced difficulty in determining the type of land form and its precise mode of origin.

Some experienced analysts in Western Canada have found that soil tone elements and their relation to microtopography are the most reliable indicators of subsurface soil conditions since they are directly related to soil texture and soil moisture. In fact, the experienced analyst, who in a particular region has made the necessary field investigations of correlating air photo patterns with subsurface soil conditions, does not necessarily have to accurately predict the geological origin of a deposit in order to determine the type of engineering soil shown in the air photo pattern.

Regarding qualifications of an analyst of glacial soils, an extensive background in glacial geology and geomorphology is essential. Furthermore, grounding in the fundamentals of soil mechanics, pedology and plant ecology is desirable and commonly enables the analyst to considerably enhance his analysis. Field experience should necessarily incorporate an extensive program of correlating air photo patterns with subsurface soil conditions. In fact experience is the main limiting factor to the amount of information that can be derived from air photo analysis.

Air Photos

Maximum utilization of air photo analysis demands high quality vertical photos at a scale in the order of four inches-to-the-mile. Larger photo scales, such as two inches-to-the-mile, preclude examination of the many microfeatures that play an essential role in analysis. Photo scales smaller than four inches-to-the-mile have a tendency to prohibit the analyst from evaluating the relative size and position of adjacent land forms. Suitable air photos at a scale of four inches-to-the-mile are presently available from the National Air Photo Library, Ottawa, Ontario and from some provincial departments.[1] Dominion-wide coverage at four -inches-to-the-mile is not presently complete. Certain areas possess coverage at an even larger scale.

Vertical air photos are nearly always taken along flight lines running east and west. Adjacent photos in the same flight line overlap 60%, whereas adjacent flight lines overlap 30%.

Stereovision

As an aid in analysis, the overlap of adjacent air photos allows the analyst to employ stereovision to obtain a three-dimensional effect. The procedure used to obtain this effort is outlined in Appendix I.

Note: Each stereopair illustration employed in this thesis is a photographic reproduction of two adjacent air photos arranged for normal stereoscopic vision.

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1 (a) Department of Lands and Forests, Government of Alberta, Edmonton, Alberta.
(b) Surveys Branch, Natural Resources Department, Government of Saskatchewan, Regina, Saskatchewan.

Mosaics

The analysis of an area covering more than ten square miles is often facilitated by the use of a mosaic. Mosaic construction involves trimming the alternate photos of each flight line and arranging them, as well as possible, to form a mosaic or "photo-map". Common practice is to photograph the mosaic and reproduce it at a scale of two miles or one-mile-to-the-inch. The air photos can then be dismantled and made available for future detailed analysis with the stereoscope. Distortions and displacements are generally characteristic of such mosaics. However, unless the inaccuracies become excessive and tend to obscure portions of the area, the analysis is in no way hindered.

Air Photo Identifying Elements

Topographic Expression

Topographic expression, an identifying element in the air photo pattern, performs two essential roles in air photo analysis.

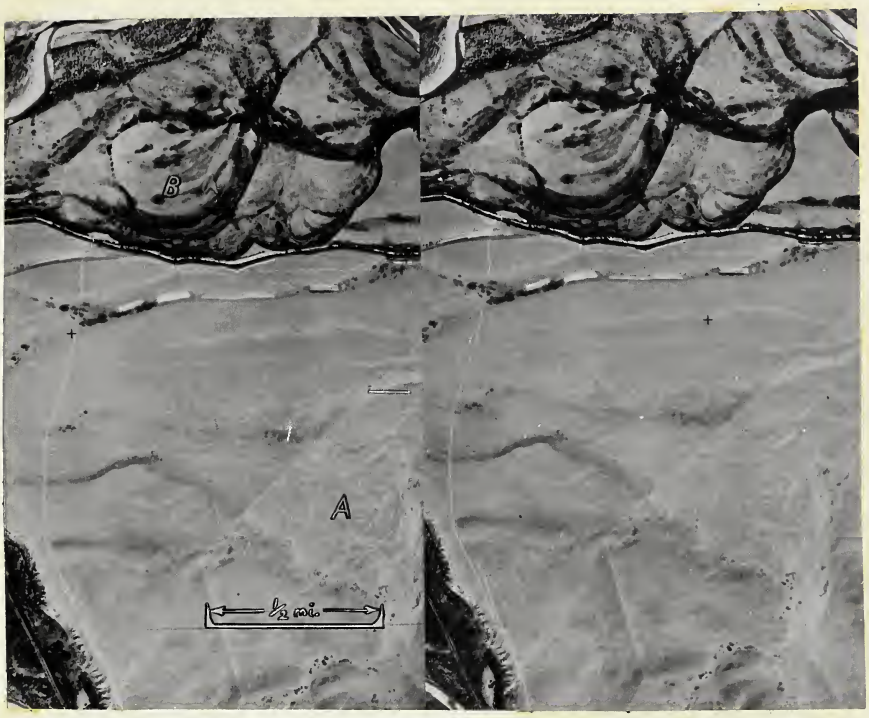
The principal use of topographic expression is in the evaluation of other air photo identifying elements such as drainage, erosion, vegetation, soil tone and land use. Features of topographic expression, particularly location and gradient of slopes and watershed areas, are essential considerations in the evaluation of the drainage and erosion elements. Vegetation and soil tones are used in the analysis for determining soil texture. These elements are partly dependent upon soil moisture, which in turn is dependent upon topography. Topographic expression must also be considered in the evaluation of land use elements. Land relief and area accessibility have marked effect on the nature and extent of land use, regardless of soil texture or structure.

The second role pertains to land form identification. Land form characteristics commonly used in analysis include size, shape, micro-topography, and the relation of a particular feature to similar and dissimilar land forms. Less common features include accordant summits, change in slope, and proximityto major drainage and undrained depressions.

Drainage

Two specific features associated with both present and abandoned drainage are often the most reliable of the air photo identifying elements. The first of these, "constructional features," are current scars, meander scrolls, and filtration basins. Constructional features are those features associated with the deposition of stream transported materials.

Current scars, resulting from deposition in fast flowing waters, are indicative of underlying sand and gravel, and thus constitute an important element in the identification of coarse-textured outwash plains, some kames, crevasse fillings and especially gravelly river terraces. Short, indistinct scars often represent a shallow dirty deposit of poorly sorted material; whereas salient scars, resembling those illustrated in A, Fig. 1, are indicative of a greater depth of clean, well-sorted sand and gravel.



T 8, R 27, W4. R.C.A.F. Photo

Fig. 1. "A" locates current scars, representative of deep sands and gravels; whereas "B" locates meander scrolls, indicative of fine and medium sand, often interbedded with thin laminae of silt and clay.

Meander scrolls are readily indentified by their characteristic shape and location on floodplain areas adjacent to low-gradient, meandering streams and rivers. The scrolls are a result of deposition on the slip-off slopes of meanders, and in the plains of Western Canada they commonly indicate a depth of fine and medium sand, often interbedded with thin laminae of silt and clay. Meander scrolls are illustrated in B, Fig. 1.

The third constructional drainage feature, infiltration basins, appears as indistinctly outlined, small, dark dots.

These basins are most regularly found on extensive sandy outwash plains where they occur in considerable numbers. In attempting to explain their mode of origin, it is thought that the infiltration basin may be scour and depositional phenomena associated with subaqueous dunes. Later infilling of organic silt and clay is no doubt responsible for soil tone pattern and apparent lack of relief.

The patterns of present-day and abandoned drainage comprise exclusively destructional drainage features. The drainage pattern, or plan of configurations exhibited by a river stream or gully, is intimately associated with the underlying soil. In the plains area of Western Canada, ordered drainage patterns such as trellis, rectangular, and parallel, are most commonly restricted to gully systems, and are indicative of a shallow drift mantle over sedimentary bedrock. Disordered, random drainage patterns of intermittent flow channels are indicative of a thick mantle of cohesive soils and are commonly observed on lake clay plains and till plains.

Whereas the greater part of the drainage of medium-and coarse-textured soils is internal, the absence of surface drainage does not imply the presence of permeable soils; for such features as water table location, vegetation, rainfall, land slope and watershed area have a marked bearing on the drainage pattern and must be accordingly evaluated.

Erosion

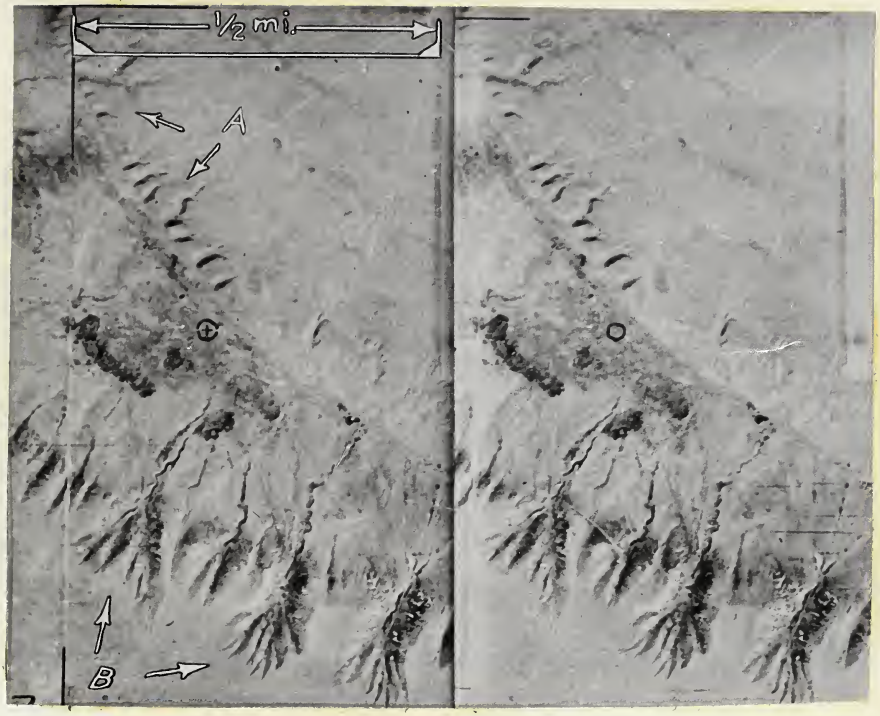
Erosion elements are a result of the following processes: wind action upon fine-grained granular soils, gullying and surface wash upon all soil types and current and wave action upon all soil types.

Wind action usually resulting in the formation of sand dunes is a reliable indicator of well-sorted, medium-sized sand. Associated with the light toned dunes are blowout pits and localized areas of bared and sparse vegetation.

Wind erosion on silt and fine sand is manifested by light-toned, sharply outlined flashes. No relief is apparent and the feature is marked solely by the abrupt change from the light tone of the drifting soil to the darker tone of more stable non-drifting soil. The erosion flashes have an environmental pattern in that they trend downwind on recently cultivated fields.

A discriminating interpretation of gully forms is essential in air photo analysis. Such features as gully length, width, shape, cross-section and gradient must be evaluated with respect to watershed area, unaltered slope of the land form, and rainfall intensity.

Short, stumpy gullies, with a high gradient and "V"-shaped cross-section, are generally reliable indicators of coarse gravel; whereas relatively larger, longer, more intricately patterned gullies of the "badger claw" type, are often found in fine gravel and coarse sand. Both gully types are illustrated in Fig. 2.



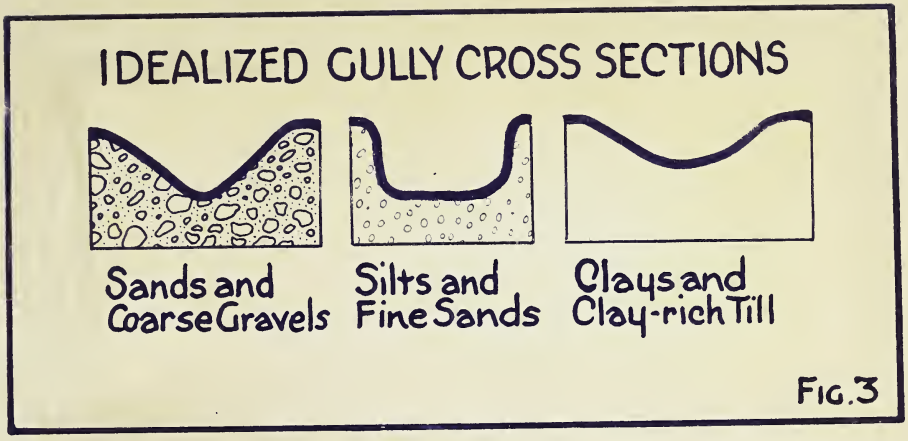
T 26, R 7, W3. R.C.A.F. Photo

Fig. 2. "A" locates typical gullies, indicative of coarse gravels; whereas "B" locates gullies of the "badger claw" type, indicative of fine gravels and coarse sands.

Silt and fine sand are very susceptible to erosion, and thus gullying in these soils is both extensive and well developed. These materials have unique gully features which are near-vertical sides and flat bottoms.

Gullies developed on lake clay and clay-rich till are shallow, long and sinuous. Gradients are low and cross-sections show softly rounded slopes.

Idealized gully cross sections are shown in Fig. 3.



Current and wave erosion by rivers and lakes results in the formation of cut banks, slumps, and uniform slopes. In all instances, these features must be evaluated with respect to the following: eroding characteristics of the adjacent river or lake, natural or unaltered slope adjacent to the river or lake, and subsurface moisture conditions. Near-vertical banks indicate cohesive soils; whereas smooth, uniform slopes in the order of 30° are commonly indicative of sand and gravel.

Slides and slumps indicate soft, cohesive soils. Where slides and slumps occur in sand and gravel, underlying strata of clay or silt may be postulated. See Fig. 4.

T 21, R 29, W1.

Fig. 4. A river-bank slide such as the one shown is commonly indicative of soft, cohesive soils.

Soil Tones

Soil tones are a significant identifying element in localized microanalysis. The tone pattern in air photos, manifesting the effect of moisture conditions as well as various soil chemical, biological and physical processes associated with surface soil profile development, is characterized by size, shade of grey, shape, blending of tones, and nature of outline or boundary. A broad generalization covering the implications of soil tones is as follows: uniform, consistent tones imply soils of uniform texture and structure; light tones imply well-drained granular soils; dark tones imply poorly drained soils, either organic or fine-textured; variations in tone pattern imply variations in moisture conditions, organic content, texture, and near-surface soil profile development.

Strip farming and other erosion preventative measures are indicative of highly erodible silt and fine sand.

Vegetation

The vegetation elements are seemingly the most difficult of the soil pattern elements to interpret. Maximum use of the vegetation elements demands local experience in the correlation of vegetative cover with photo pattern. The most significant information derived from an examination of vegetative patterns concerns the subsurface moisture content conditions. Muskeg and springs can be readily identified and outlined by their characteristic vegetation pattern. Similarly, due to the infilling of depressions and hollows by fine-grained, organic soils and the subsequent concentration of moisture and vegetation, meander scrolls, slumps, kettles, and swales may be readily identified. Advanced photo interpretation, based on vegetative species and their patterns, is beyond the scope of this project.

Land Use

Maximum farm productivity necessitates that farm management practices be intimately correlated with the soil, moisture, and topographic conditions. Thus, intensive cropping on level areas is commonly indicative of well-drained, lacustrine, clay-rich soils; whereas intensive cropping on gently undulating areas may be indicative of clay-rich till soils. Associated with cropping on till soils are field rock piles which appear as microfeatures on high quality photos. Fig. 5 illustrates a typical field rock pile.

Fig. 5. Illustrated is a field rock pile, indicative of cultivated till soils. On an air photo, this rock pile would appear as a bright dot, sharply outlined and encircled by a dark ring, being slightly elongated in the direction of field plowing.[1]

[1] Mollard, J.D. "Aerial Photographic Studies in the Central Saskatchewan Irrigation Project," Cornell University, 1952.

CHAPTER II

Glacial Land Forms, Their Topography Origin, Composition, Engineering Significance and Air Photo Pattern

To facilitate the introduction of analysis to the soil engineer wishing to use air photos in Western Canada, characteristics and air photo patterns of common glacial land forms that he will probably encounter are presented in this chapter. The land forms discussed are important both with respect to areal extent and with respect to possible sources of granular material. Details of land form topography and origin possibly significant to the engineer are presented in brief form. In addition, important engineering features of constituent materials -- texture, structure, grading, organic content and expected variability -- are presented. Soil characteristics, necessarily associated with land form, influencing exploration, design, construction and maintenance are discussed briefly.

The air photo pattern of each land form is discussed and illustrated by means of stereopairs of readily identifiable land form examples. Each important element composing the air photo pattern is discussed and, where both possible and practical, emphasis has been placed on the identification of soil texture and structure rather than on the identification of land form.

The sequence of land forms presented in this chapter has been arranged generally according to soil texture and structure. Land forms mainly composed of unsorted drift are presented first. Glacial land forms commonly containing a predominance of sorted sand and gravel are presented secondly. Finally those land forms composed of the fine-grained lake sediments are presented.

End Moraine

Topography

To facilitate discussion, types of terminal and recessional moraine are grouped together and discussed under the heading of "End Moraine."

In the general sense of the term, end moraine consists of a belt of disordered hills, ridges and depressions. The topography may vary from a surface formed by an aggregation of gently sloping smooth hills, to a rugged, irregular surface of steeply sloping hills and depressions. End moraine occasionally appears as a roughly parallel series of disordered hills, although even then the disordered pattern of hills is evident.

An abundance of glacial meltwater, commonly originating at the ice front and sorting, but not transporting, debris released by the melting ice usually results in a granular-rich drift. An aggregation of hills and mound having such an origin is, strictly speaking, a kame moraine and is therefore discussed later under the heading of "Kames."

Origin

A halt during the advance or retreat of an active ice sheet results in the formation of end moraine. The size and extent of the end moraine is dependent on the duration of the halt, the velocity at which debris is brought up to ice front and the concentration of drift in the active ice mass. An ice front, oscillating within narrow limits and thrusting the drift into ridges, results in a roughly parallel series of disordered hills and depressions.

Composition

A characteristic end moraine texture and structure exists, though ranging within relatively wide limits from one area to the next. Most of the material making up an end moraine is termed till and is essentially unsorted and nonstratified, and is a mixture of gravel, sand, silt and clay. Lenses, bands and zones of sorted material of all sizes occur erratically throughout the till.

Engineering Significance

The rugged relief associated with end moraines commonly restricts engineering projects to highways, railways, pipelines and small dams for storage purposes. Perhaps the most important construction problem is the extensive cut and fill necessary to maintain reasonable grades. Numerous undrained depressions, often containing muck and organic soils, give rise to problems associated with both drainage and bearing capacity. Highway design and construction must necessarily cope with the erratic distribution of sorted materials. Glacial till is usually an ideal fill material. It contains sufficient granular material to develop an angle of internal friction, and the clay fraction is large enough to develop cohesive strength and reduce the permeability to a generally insignificant amount. As end moraine is seldom overridden by ice, unit weights are low and excavation costs are relatively cheap, except of course when the end moraine is bouldery. Proctor moisture-density curves are not peaked, and thus during compaction, field moisture contents are not critical.

Air Photo Pattern

(i) Topographic Expression: The topographic expression is simply that produced by a mass of disordered hills, ridges and depressions. The depressions commonly contain sloughs and present an irregular outline.

There is no accordance of water levels, nor is there seldom an accordance of summits.

(ii) Drainage Pattern: Drainage development is at a minimum since sloughs can usually hold all runoff during a normal season. Where drainage is developed in a localized watershed, the pattern is irregular and conforms to the haphazard topographic expression.

(iii) Erosion: The erosion of knoll summits by surface runoff and wind action is revealed in air photo patterns by soil tone elements only, and thus is discussed under the heading of "Soil Tone." Eroded gully systems are apparently poorly developed in the end moraines of Western Canada. Surface runoff along natural draws or constructional features forms a "ghost drainage" pattern, also discussed under the heading of "Soil Tone."

(iv) Soil Tone: Near-surface influence of the limy B horizon and concentration of a thin coarse-textured surface layer sand and gravel on the tops of hills and ridges result in light tone summits. Toward the depressions, slope tones gradually blend from light to grey, and, finally, to dark grey and black in the depressions. The "ghost drainage" pattern is due to accumulations of fines and organic matter in natural draws. Soil tones in the depressions are dark and blend gradually into the grey tones of the adjacent slopes.

(v) Land Use: The rugged relief of end moraine is reflected in the winding pattern of unimproved roads and trails. Relief causes the otherwise arable soils of end moraines to be left for grazing purposes; hence pasture is common on this land form.

Photos of end moraine examples are presented in Fig. 6 and Fig. 7.

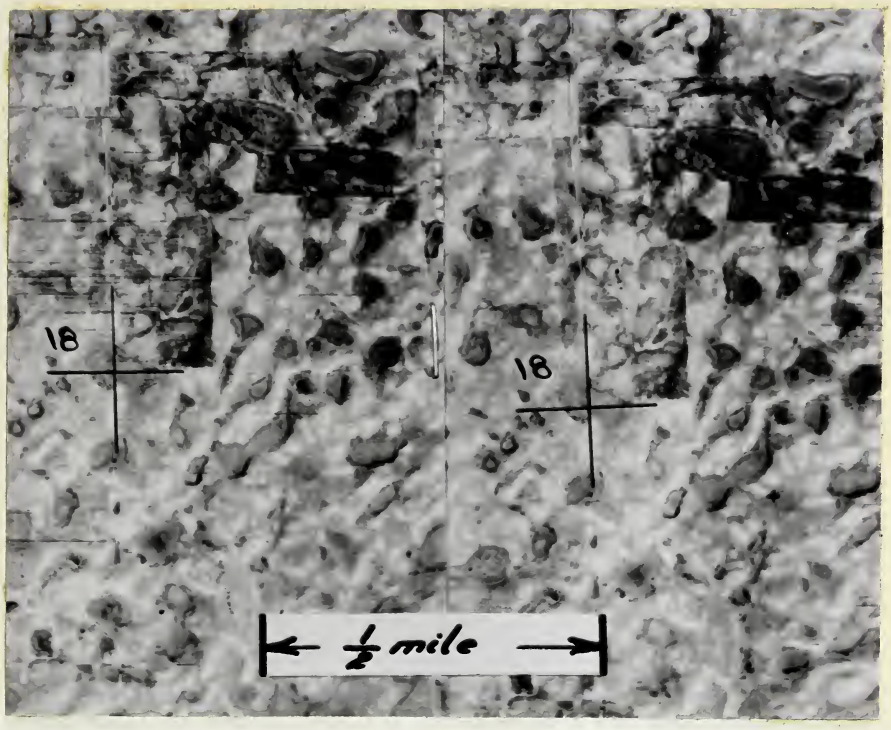


Fig. 6. T 19, R 16, W3. R.C.A.F. Photo.

The jumbled mass of hills, ridges and depressions is commonly characteristic of end moraine. Light tones of knoll summits, contrasted with darker tones of the depressions, and ghost drainage patterns are similarly characteristic. Difficulties encountered in cropping such topography are readily reflected by the pattern of limited land use.

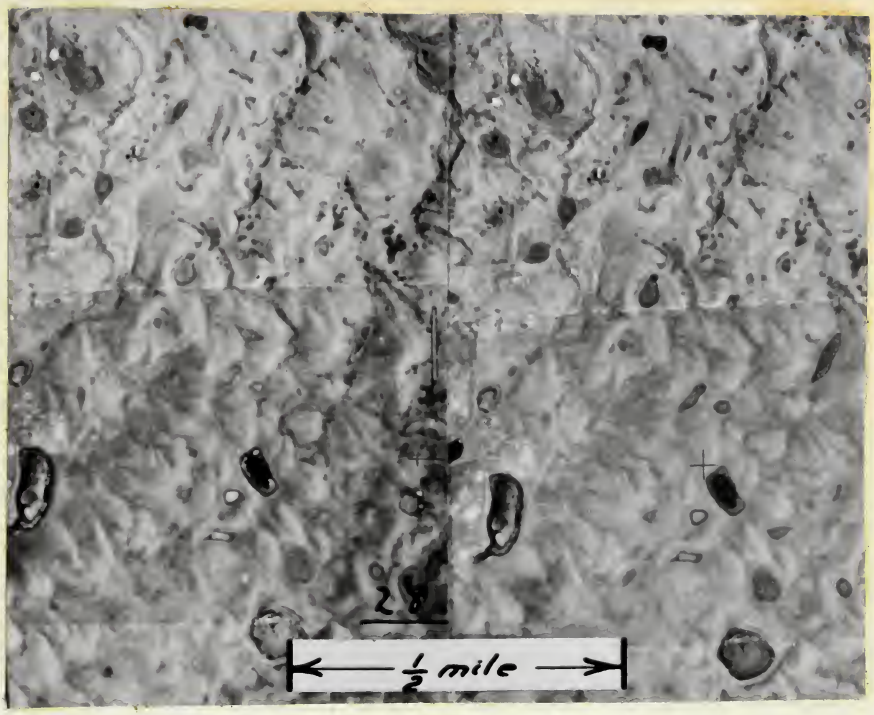


Fig. 7. T 12, R 26, W3. R.C.A.F. Photo

This end moraine illustrates an ideal example of thrust-deformation. During deposition of the drift, the ice front locally parallelled a northeasterly direction. The dark band across the area marks a field where grazing practices have differed from those followed to the north and south.

Till Plains

Topography

Till plains are found over a large portion of Western Canada. The soils of till plains, deposited under overriding ice sheets, is often remarkably uniform over large areas. The topography is undulating to gently rolling, and has been termed "swell and swale." Many sloughs and undrained depressions are scattered haphazardly over till plains.

Composition

The soil composing this land form is glacial till and, as in end moraines, is essentially an unsorted, nonstratified mixture of gravel, sand, silt and clay. Lenses of sorted material often occur erratically throughout the till. However, their occurrence can seldom be termed excessive.

Engineering Significance

Relatively few engineering problems are associated with till plains. As previously mentioned, till is generally suitable for highway fills. Occasionally, less desirable silt-rich till is encountered and presents problems of stability and frost heaving. Drainage problems associated with shallow sloughs and depressions are commonly of a minor, localized nature.

Air Photo Pattern

(i) Topographic Expression: Undulating to gently rolling topography is characteristic of till plains. Undrained depressions and sloughs, scattered haphazardly over the plains present irregular outlines.

(ii) Erosion: Wind erosion on till plains is limited to the removal of organic material and fine soil fractions from the crests and summits of knolls. Such erosion is not so much reflected by topographic expression but, rather, by soil tone. Till plain gullies, similar to those in clay plains, are long and winding, and have low gradients and softly rounded side slopes.

(iii) Soil Tones: Dark tones of depressions and light tones of knolls comprise the soil tone pattern. In most cases, the change from light to dark is gradational. The light tones of the knolls often appear as mere, faint blushes.

(iv) Land Use: Maximum land utilization is attempted, but is often impeded by depressions and sloughs. Field stone piles, an identifying element of cultivated till plains, can be readily identified on small-scale, high-quality photos.

Photos of till plain examples are illustrated in Fig. 8 and Fig. 9.

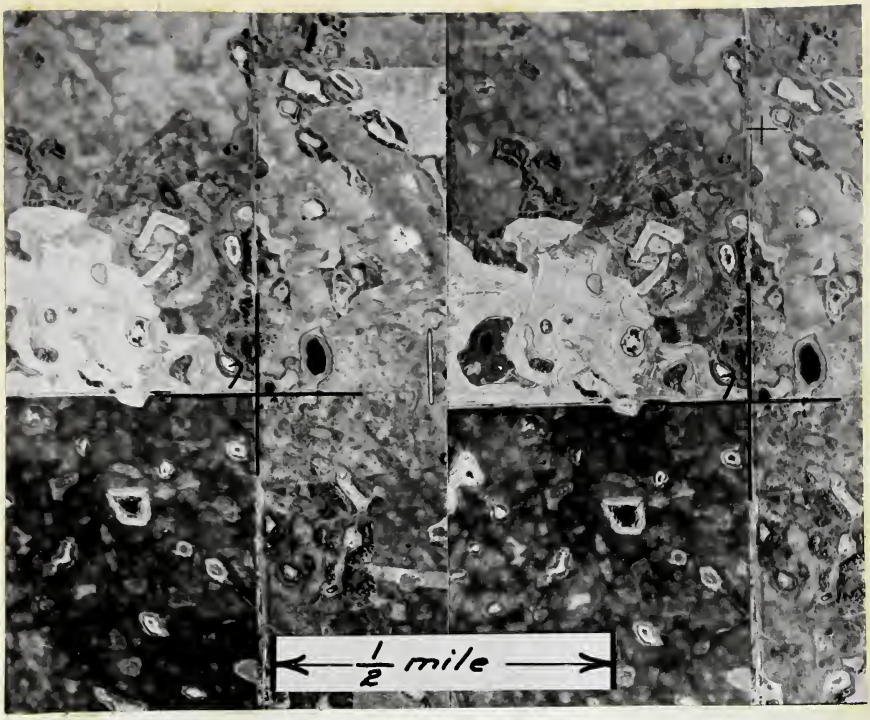


Fig. 8. T 33, R 4, W2. R.C.A.F. Photo.

Undulating to gently rolling topography, exhibited in this example, is characteristic of till plains. Sloughs, scattered haphazardly over the plain, reflect the impervious nature of the soil. The soil tone pattern is typical and constitutes the main air photo identifying element.

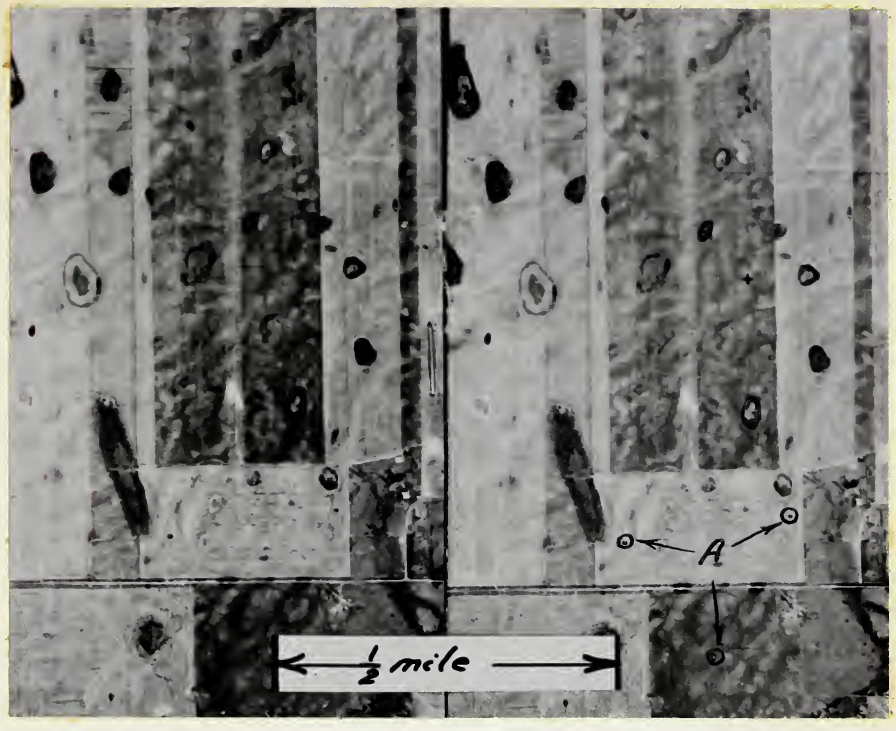


Fig. 9. T 28, R 6, W3. R.C.A.F. Photo

This air photo portrays a pattern comprised of the elements of topographic expression, erosion, soil tone, and land use; this pattern is characteristic of till plains. "A" locates field stone piles that appear as small white dots, surrounded by a dark ring, often elongated in the direction of field plowing.

Boulder Pavements

Topography

With respect to areal extent, boulder pavements are of minor importance. However, as they represent a source -- often the only source -- of riprap in the prairies, a discussion of them is warranted. Boulder pavements are restricted to bordering abandoned glacial spillways and along the sides of present-day drainage channels. The boulder-studded surface is occasionally terraced, but is commonly level or gently sloping toward the channel. Local microrelief is limited to shallow scour basins. Where the boulder pavement constitutes a thin mantle over bedrock, the scour basins exhibit a lineal pattern. Commonly, there is no bedrock influence, and the scour basins present a random pattern.

Boulder pavements are a result of river erosion upon bouldery till plains or end moraine. Clay, silt, sand and even gravel sizes have been removed, leaving a thin, boulder-rich mantle. As the boulder pavements are a river-cut feature, they are commonly associated with terraces.

Engineering Significance

As previously mentioned boulder pavements often represent the only source of riprap for earth dams in the prairie provinces. The boulder-pavement mantle is thin and seldom extends below a depth of four feet. Boulders range between $\frac{1}{2}$ cubic foot to $\frac{1}{2}$ cubic yard in size.

Air Photo Pattern

Topographic Expression: Boulder pavements, associated with abandoned or present-day drainage, are either terraced, flat, or gently sloping toward the channel. Small-scale, high-quality photos show both the larger boulders and the scour basins.

Soil Tones: Light tones of the localized highs, dark tones of the vegetated scour basins, plus the light specks of the larger boulders constitute a characteristic soil tone pattern.

Land Use: The predominance of boulders precludes use of the land for any purpose but grazing.

Fig. 10 illustrates on example of boulder pavement.

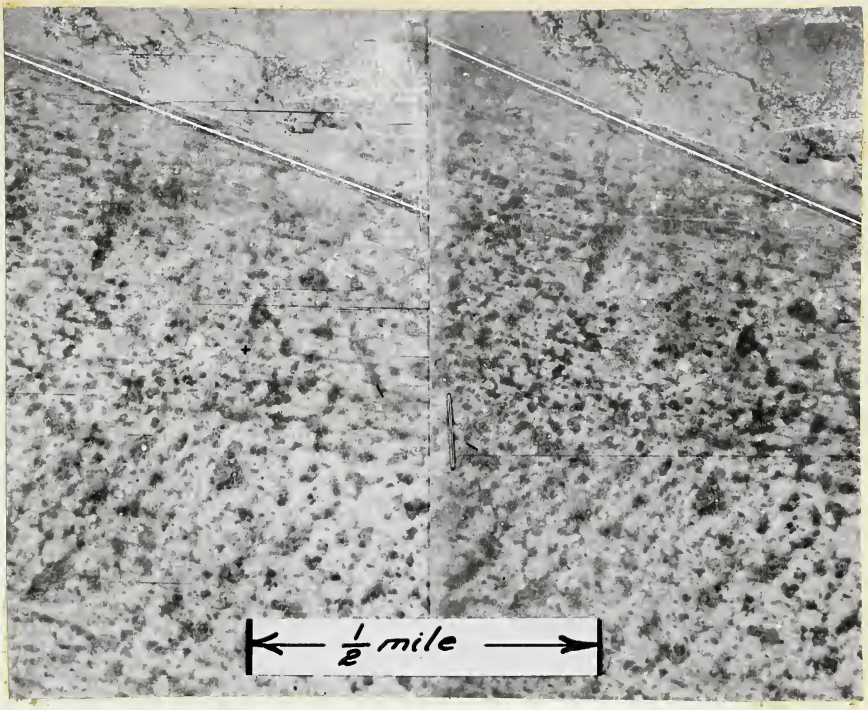


Fig. 10. T 1, R 6, W3. R.C.A.F. Photo.

The random pattern of the scour basins indicates the lack of bedrock influence on the boulder pavement in the lower right. However the bedrock influence is manifested by lineations in the upper and lower left. The pattern of the scour basins is accentuated by heavier vegetative growths in the basins. Close examination discloses the larger boulders. Note the similarity between the boulder pattern and the pattern of high sulphate concentration north of the railroad.

Kames

Topography

Kames have a very limited distribution in the prairie provinces. However, discussion is warranted as these land forms constitute the major source of sand and gravel in upland areas, remote from abandoned and present-day drainage.

Kames commonly appear as rugged, massive hills and ridges. Side slopes are characteristically steep and are often interrupted by numerous draws and gullies.

Kames occurring in great numbers form what is called a kame moraine.

Kames originate very close to the front -- either in holes in the surface or along the margin -- of wasting ice sheets and represent the coarse fraction of the glacial debris that has been washed and sorted by glacial meltwater.

Composition and Engineering Significance

Kame composition is characteristic of the stratified, ice-contact land forms. Constituents are predominantly sand and gravel. Marked variations in texture and structure are commonplace. Zones, bands, and lenses of clay, silt and till occur erratically throughout the kame.

Excavation against open faces is advisable in order to mix the segregated materials.

Air Photo Pattern

(i) Topographic Expression: Kames appear as rugged, massive hills and ridges that display a peculiar lumpy or knobby (walnut-like) surface expression. Steep side slopes, reflecting the granular nature of kames,

are also characteristic.

(ii) Erosion: The most significant element in the identification of kames is the so-called gravel gully. Such gullies are usually common on kames and enable the analyst to rapidly discern the difference between kames and adjacent hills and knolls of till. Incised cattle trails are indicative of granular soil.

(iii) Soil Tones: Soil tones are necessarily those of isolated, well-drained granular soils. Knoll summits and crests appear light, whereas depressions and draws appear dark due to accumulations of fines and organic matter.

(iv) Land Use: Rugged relief plus droughty granular subsoil usually preclude extensive cropping on kame soils. Gravel pits are usually observed in the kames located in less remote areas.

Figs. 11, 12, 13 and 14 illustrate readily identifiable examples of kames and kame moraine.

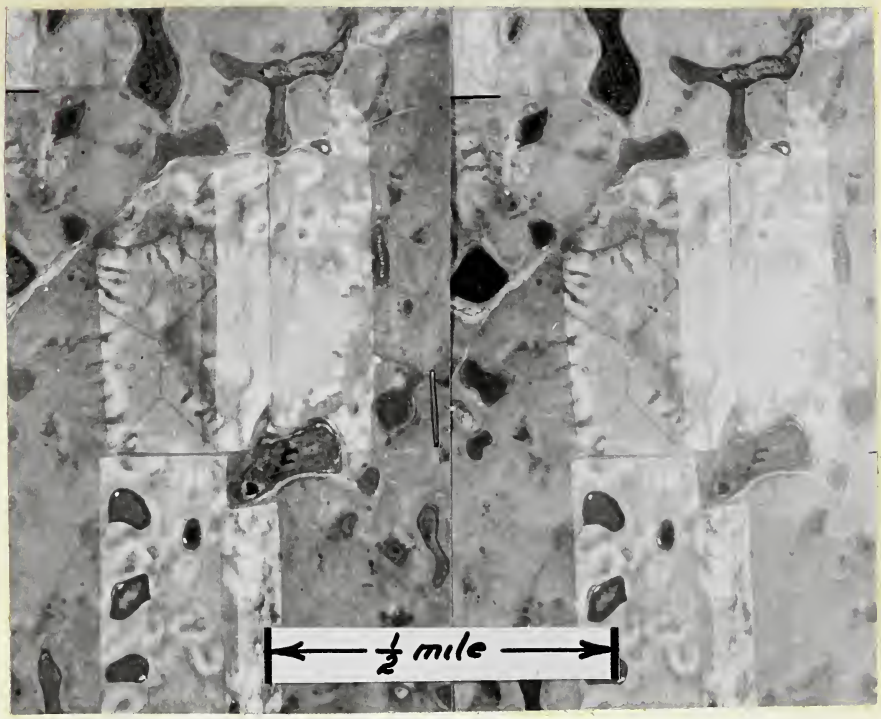


Fig. 11. T 16, R 3, W3. R.C.A.F. Photo.

The stereopair illustrates readily identifiable kames. The isolated, massive form plus the steep side slopes interrupted by gravel gullies are characteristic. Note the pattern differences between the kames and the enclosing end moraine.

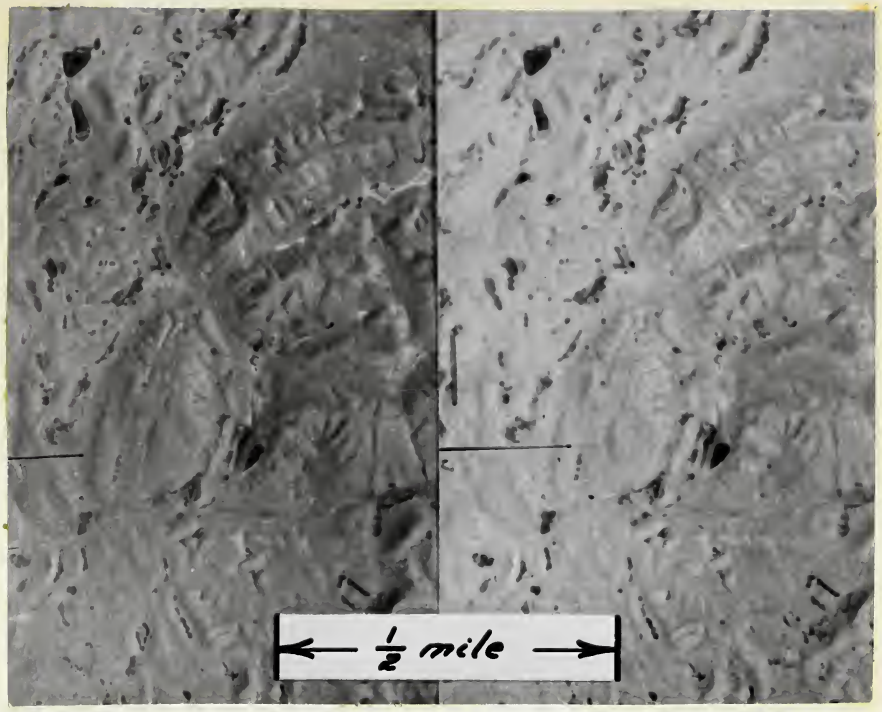


Fig. 12. T 18, R 7, W3. R.C.A.F. Photo.

Differences between kames and end moraine hills are readily illustrated in the stereopair example. Note the gravel gullies, exclusively located on the kame side slopes.

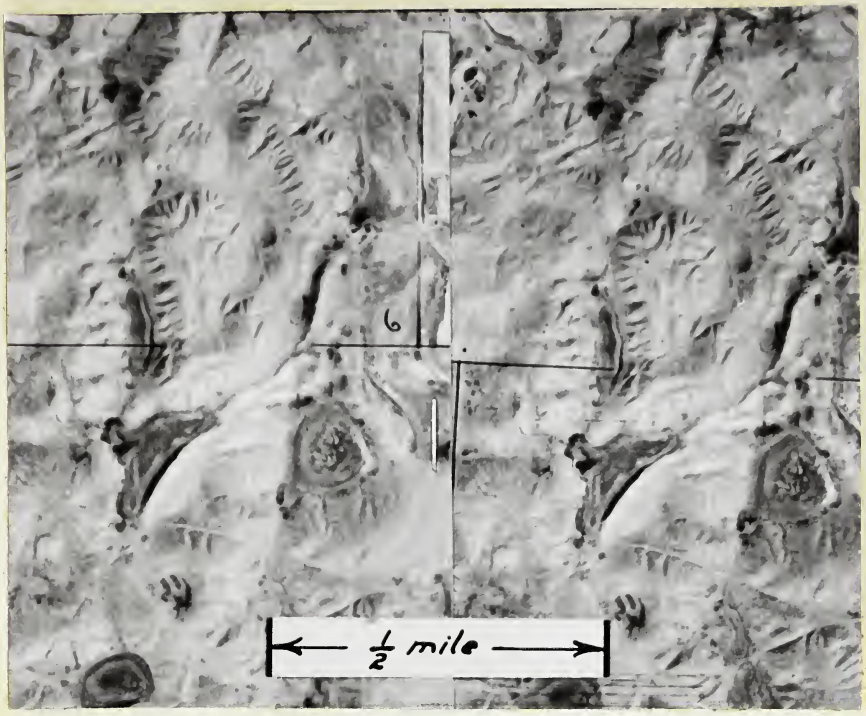


Fig. 13. T 18, R 7, W3. R.C.A.F. Photo.

Gravel gullies are possibly the sole identifying element in this stereopair example of a kame moraine.

Fig. 14. T 26, R 9, W3. R.C.A.F. Photo.

The stereopair illustrates an area of relatively complex subsurface soil conditions. However, three readily identifiable kames are visible, and no doubt contain the better sorted material in the area.

Eskers

Topography

Eskers represent a minor source of granular material in Western Canada. The characteristic topographic expression of an esker is a long, sinuous, steep-sided ridge with a height commonly varying from a few feet to a hundred feet. The length of an esker is extremely variable and may range from a fraction of a mile up to the order of five miles. Few eskers are continuous over their entire length and gaps and constrictions are common --thus the term "beaded" eskers. Crests, seldom level over any distance, are commonly hummocky or gently undulating. Esker tributary and distributary systems, resembling normal stream patterns, are often observed.

Origin

Most common theory on the origin of eskers attributes them as bed load deposits of subglacial streams that flowed through stagnant, wasting ice sheets. Supporting this theory is the fact that eskers are regularly restricted to kame moraine and end moraine areas. A shallow mantle of outwash or lacustrine sediments over these areas does not appear to preclude the existence of esker.

Composition

The common constituents of eskers are granular in texture. As a rule, gravel sizes predominate, though sorting is poor and abrupt changes in texture are commonplace. Clay seams, large boulders, and zones of unsorted till are often noted in exposed cuts. The organic soil profile development, thickest on the lower slopes, becomes increasingly thinner towards the esker crest. Also, a mantle of glacial till is often found on the esker crest.

This mantle has been identified as till released from debris-laden ice that collapsed and later melted upon the surface of the esker. Shallow, elongated depressions, which often parallel the sides of eskers, are remnants of subglacial channels, and have been named "esker troughs." They are commonly filled with moist, organic silt and clay.

Engineering Significance

The areal extent of eskers in the western prairie provinces constitutes far less than 1% of the area, and thus the only engineering significance of eskers is that they may occasionally be a source of sand and gravel. In the exploitation of eskers for road construction, it is often desirable to work against an open face in order to mix any segregated materials. Shallow testholes showing glacial till on the crest of an esker should not discount the possibility of granular material at greater depths.

Air Photo Pattern

The important air photo identifying elements are topographic expression and soil color tones. Occasionally, erosion and land use identifying elements constitute substantiating evidence.

(i) Topographic Expression: The important feature of the topographic expression is a long, sinuous ridge with steep side slopes and relatively narrow width.

(ii) Soil Color Tones: Regardless of land use practices, esker ridges appear very light in color tone. The well-drained nature of the soil plus the exposure of the limy B soil horizon by surface runoff and wind erosion are responsible for the light tones. Contrasting with the light tones are

the dark tones of the moist organic soil of esker troughs paralleling the lower slopes of eskers. Usually the steeper and higher the side slopes and sharper the crest, the coarser the subsurface materials.

(iii) Erosion: Short, stumpy, gravel gullies are not, as a rule, common eskers. However, their occurrence is a reliable indicator of granular material. Cattle trails that cross esker ridges are often more incised than trails crossing ridges of less granular soil.

(iv) Land Use: The existence of any gravel pits in an elongated ridge is usually indicative of an esker.

Photos of esker examples are presented in Fig. 15 and Fig. 16.

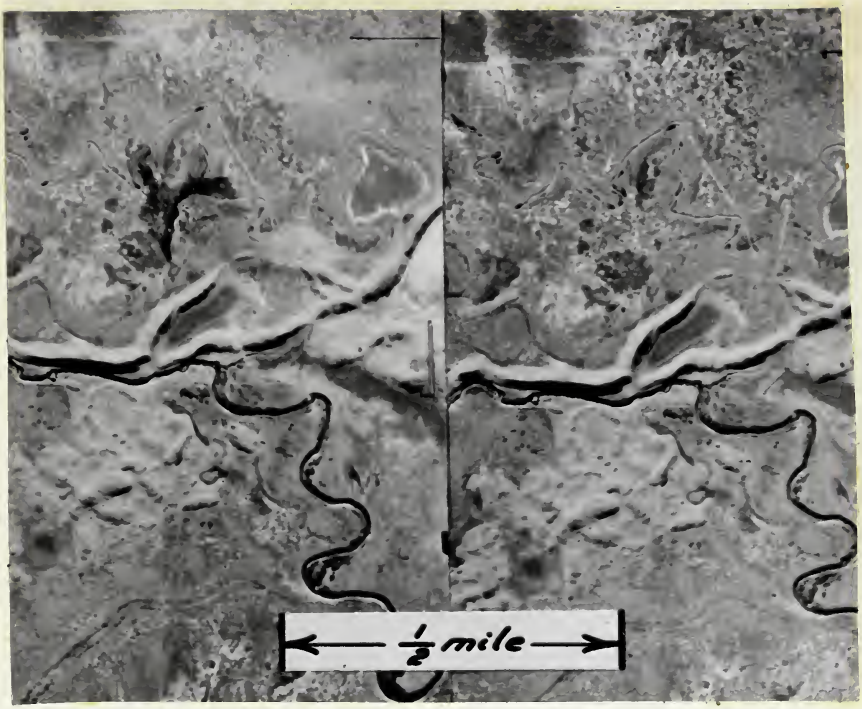


Fig. 15. T 38, R 8, W4. R.C.A.F. Photo.

Soil tones and topographic expression accentuated by shadow, readily identify this esker. Note the bifurcation, gaps and constrictions occurring along the esker length. The small stream alongside the esker is located in an esker trough. Light-toned mounds in the southeastern portion of the area are probably moulin kame deposits and granular in composition. The delicate pattern of white tones to the north and south are indicative of high sulphate concentrations at ground surface.

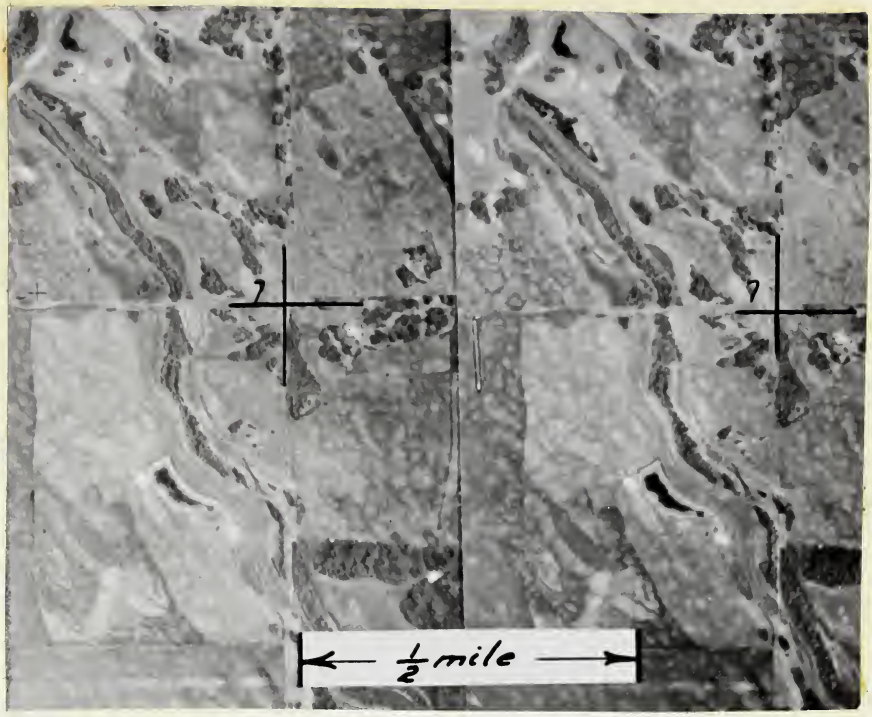


Fig. 16. T 30, R 8, W3. R.C.A.F. Photo.

Characteristic topographic expression and marked variations in land use constitute the major identifying elements of the esker. Note the northernmost portion of the esker, where light soil tones indicate the well-drained, granular nature. Esker troughs border the esker and, in some places, are filled with muck.

Crevasse Fillings and Gravel Deltas

Topography

Crevasse fillings and delta plains, though relatively uncommon glacio-fluvial land forms, represent sources of granular material, and thus warrant discussion here. Their characteristic topographic expression is an isolated mesa-like form, with steep side slopes and a flat top. Pits or kettles, caused by melting of stranded icebergs, are often located on the land form surfaces. Crevasse fillings are relatively long and narrow; whereas delta plains are commonly elliptical in plan and exhibit a nose-like terminal.

Origin

Crevasse fillings are thought to represent the bed load deposits of streams that once flowed through open cracks of stagnant, wasting ice sheets. Gravel deltas, on the other hand, are composed of granular material deposited in standing water at the mouths of glacial streams. Crevasse fillings commonly exhibit ice contact features in the form of steep sides on kettles. Gravel deltas also exhibit steep sides, some due to deposition of coarse sand and gravel at the angle of repose, others possibly due to ice contact.

Composition

Land form constituent materials are commonly poorly sorted sand and gravel, though it is true that some small glacial deltas are quite well sorted. Due to the proximity of ice masses, rapid variations in composition are characteristic, and zones of clay, silt and till may be expected to occur

erratically. Of the three related sources of granular material -- eskers, crevasse fillings, and gravel deltas -- the latter is thought to contain the better sorted material. The organic soil profile development is commonly poorly developed on both land forms, though the limy B horizon may predominate and extend to a depth of three feet or so.

Engineering Significance

The negligible areal extent of crevasse fillings and gravel deltas limits their engineering significance to sources of sand and gravel. In each case, the depth of granular material should at least equal the height of the land form. As in eskers, it may prove advisable to work on open faces to mix the segregated materials.

Air Photo Pattern

(i) Topographic Expression: Steep sides, flat top, and projection above the immediately surrounding area are diagnostic features.

(ii) Drainage: Drainage pattern features are almost invariably absent; and thus the permeable nature of these land forms is reflected in the soil pattern. Current scars, indicative of gravels, are occasionally present on some large gravel deltas.

(iii) Erosion: Crevasse fillings and gravel deltas may exhibit characteristic gravel gullies. Wind erosion features may be present if surface soils are of a fine sand or silt texture.

(iv) Soil Tones and Vegetation: The well-drained nature of these land forms is reflected in light uniform soil tones and a generally sparse cover of prairie grass.

(v) Land Use: Gravel pits are obviously important elements in the identification of these land forms. Gravel pits cannot be readily separated from highway borrow pits. Borrow pit features that are diagnostic but different from those of gravel pits are a location immediately adjacent to both roadways and fill areas and a pattern of systematic, efficient excavation.

A readily identifiable crevasse filling is illustrated in Fig. 17; whereas a readily identifiable gravel delta is illustrated in Fig. 18.

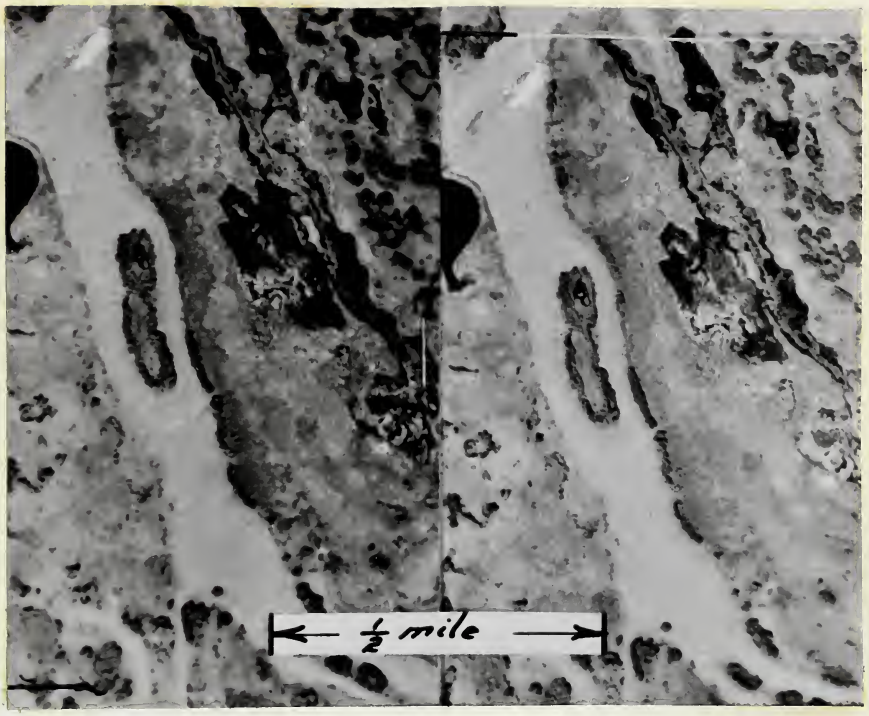


Fig. 17. T 12, R 32, W1. R.C.A.F. Photo.

This crevasse filling is readily identified by its characteristic topographic expression: flat top, steep sides and relatively narrow width. Note the marked uniform, light soil tone and nearly imperceptible gravel gullies accentuated by cattle trails. A gravel pit is located in the northernmost portion of this crevasse filling.

Fig. 18. T 24, R 2. W5. R.C.A.F. Photo

This gravel delta examples resembles a crevasse filling in many ways, e.g., flat top, steep sides and mesa-like form. The characteristic light tone suggests a relatively uniform deposit, though variations at greater depths are not reflected in the soil pattern. Available granular construction material in this source might very well approximate three and one-half million cubic yards.

Outwash Plains

Topography and Origin

Outwash plains constitute an important source of granular material in upland areas remote from present-day drainage channels. These deposits of sand and gravel, eroded and transported from the ice front by glacial meltwater, vary from narrow valley fillings to extensive alluvial fans that cover many square miles.

Two broad classes of outwash plains exist. The first, pitted outwash plains, are thought to have been deposited over and around thin remnants of stagnant, wasting ice sheets. Later melting of these remnants resulted in pits and depressions, commonly termed kettles. Occasionally the kettles, frequently aligned as links of a chain, may be so numerous that no vestige of the original plain surface remains. The topography, that of a mass of disordered hills and ridges, may be readily mistaken for end moraine topography.

Unpitted outwash plains is the second great class of outwash plains. Sand and gravel forming these plains are thought to have been deposited in territory remote from any ice sheet remnants. Kettles occasionally occur and are thought to arise from the melting of small icebergs that were stranded along shallow glacial streams. The topography of unpitted outwash plains is generally flat, although terraces are occasionally noted in plains that border present-day drainage channels. The latter are referred to in geological literature as valley trains.

Composition and Engineering Significance

Granular deposits of outwash plains are relatively well sorted. Deposits of sand and silt are usually found in the larger plains and gravel deposits are generally restricted to the smaller plains. As in other glacial deposits of stratified material, variations in texture and structure are characteristic. However, the variations are not extensive nor as significant as those found in kames and eskers. Heavily pitted outwash presents problems of extensive highway cut and fill. Soil drifting may occur on sandy outwash plains; whereas frost heaving and low stability may present problems on silty outwash plains.

Air Photo Pattern

(i) Topographic Expression: A level surface, occasionally interrupted by abandoned channels, terraces and kettles, is the most important element in the identification of unpitted outwash plains. In heavily pitted outwash plains, topographic expression is used in the evaluation of erosion elements.

The nature and extent of adjacent land forms is important, especially when marked changes in elevation occur.

(ii) Surface Drainage: Due to the pervious nature of most outwash plains, few post-depositional drainage features are observed. Constructional drainage features -- that is, those formed at the closing stages of outwash deposition -- are most important. Current scars are indicative of gravels; whereas infiltration basins are generally indicative of sand. Features due to wind erosion are common on the extensive deposits of sand and silt.

Gullies are common on steep side slopes and exhibit patterns characteristic of the soil texture.

(iii) Soil Tones: The well-drained, granular nature of the outwash soil is reflected in light tones. Current scars and infiltration basins, which seldom exhibit marked topographic expression, are manifest by their soil tone patterns.

(iv) Land Use: Gravelly outwash plains are generally left for grazing; whereas sandy and silty outwash plains are occasionally cropped and necessitate erosion preventative measures.

Figs. 19, 20, 21 and 22 illustrate readily identifiable outwash plains.

Fig. 19. T 44, R 8, W3. R.C.A.F. Photo.

Current scars, kettles and infiltration basins are identifiable in this stereopair example of an outwash plain. To the northwest, the area rapidly grades into a heavily pitted outwash plain. Note the similarity between the pitted outwash topography and the end moraine topography illustrated in Fig. 6.

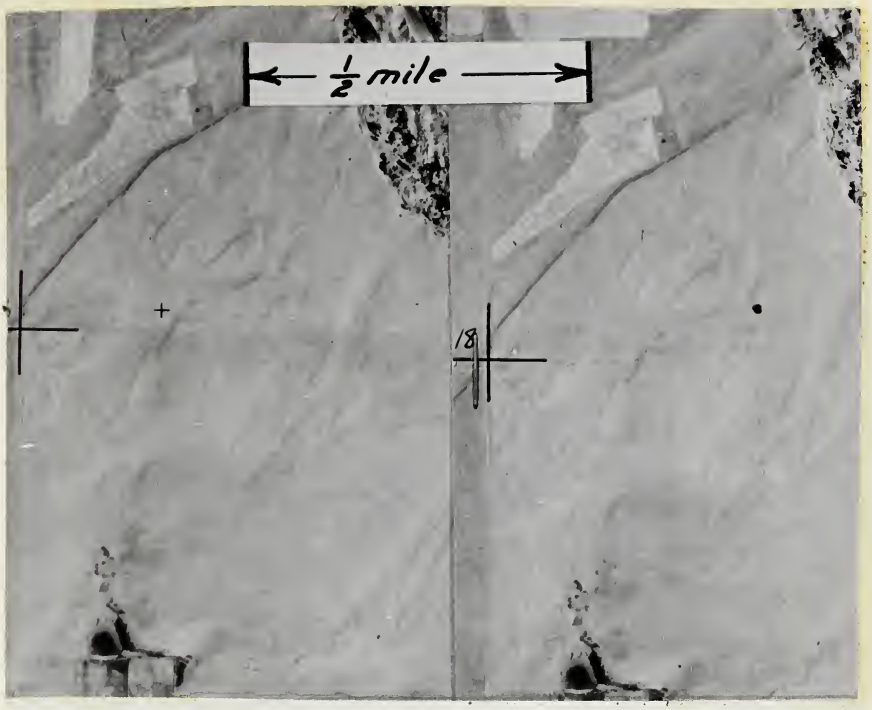


Fig. 20. T 9, R 1, W5. R.C.A.F. Photo.

Current scars, terraced surface and uniform soil tones are the important identifying elements of this gravelly unpitted outwash plain. Note both the abandoned channel trending northeast and an ice contact feature in the southwestern portion of the area. Slumping is present along the slopes of the stream in the northeastern portion of the area and is indicative of underlying soft cohesive soils. Because of the coarse texture of this deposit it is not suited to arable farming and so remains in pasture.

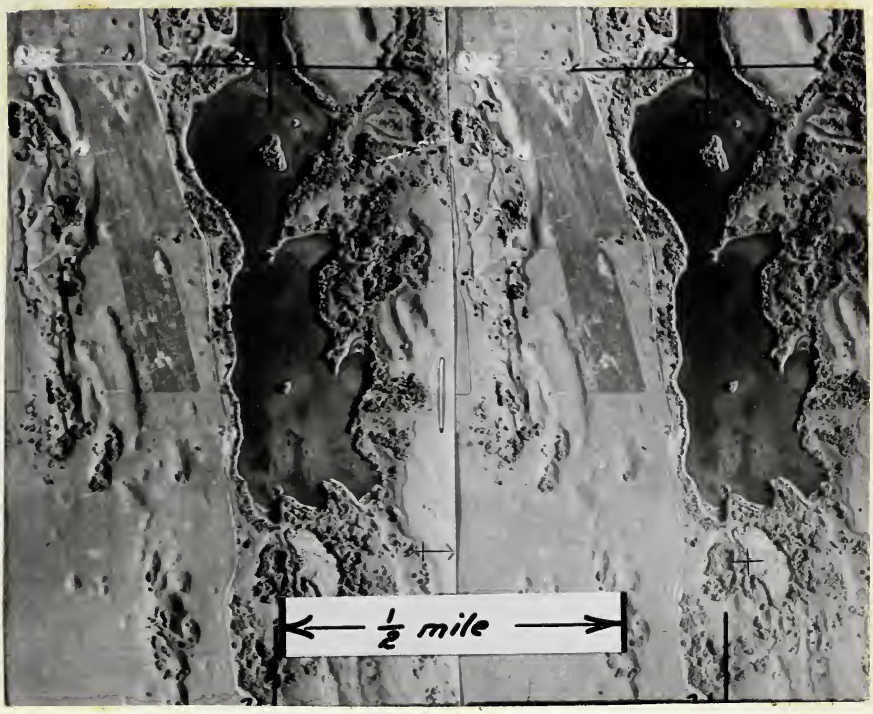


Fig. 21. T 35, R 5, W2. R.C.A.F. Photo.

Pitting in this outwash plain is not extensive and the level surface is readily recognized. Only coarse granular material would allow the steep side slopes exhibited by the deeper kettles. The delicate topographic expression of the kettle in the western portion of the area is classic and reflects the surface configurations of the ice remnant which once filled the depression. Note the small gravel pit alongside the east-west road.

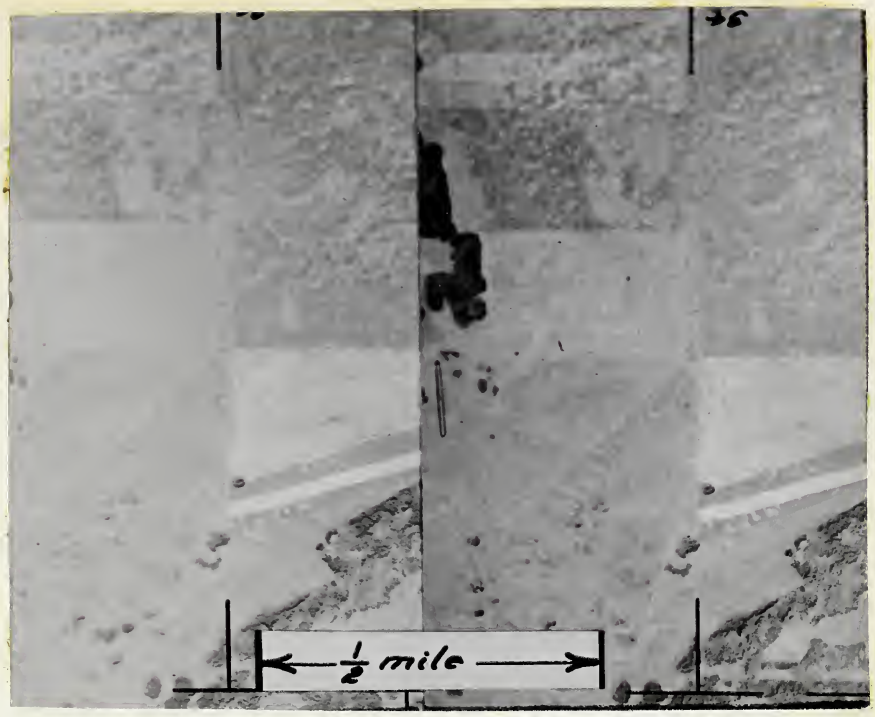


Fig. 22. T 22, R 29, W1. R.C.A.F. Photo.

Infiltration basins and kettles are the main identifying elements of this sandy outwash plain. Note that the infiltration basins in particular are more apparent on dark fallowed fields than on lighter-toned, grain and pasture fields.

Glacial Lacustrine Deposits

Topography

Deep deposits of clay, silt and sand usually exhibit little relief, and the topography of such deposits is best described as level to gently undulating. Where wind action upon lake sand has occurred, dunes and related wind-drift phenomena may occur. Shorelines and strand areas surrounding lake deposits may, if the lake was large and comparatively long-lived, reveal gravelly or sandy beaches, bars and wave-cut cliffs.

Origin and Composition

The extensive lacustrine deposits in Western Canada owe their origin to large, proglacial lakes that were filled with glacial meltwater carrying sediment released from melting ice. Other glacial lakes, usually much less extensive, were formed in low-lying areas beyond the ice margin. Relationships between topography, location of area being tested relative to shorelines, and physical composition do exist but are seldom determined and employed in analysis.

Engineering Significance

Associated with advantages of minimum cut and fill in lake clay areas are the disadvantages of poor subsurface and surface drainage. High water tables, excessive settlement, and low bearing capacity are additional related problems. Lake silt imposes problems of low bearing capacity and frost heaving.

Highway problems in lake sand are almost negligible; in fact sand is frequently sought for sub-base material. Wind erosion in active dune areas may uncover shallow pipelines.

Air Photo Pattern - Lake Clay

Topographic Expression: Variations in relief are negligible on the deep, extensive deposits. Shallow mantles of clay commonly assume the topography of the underlying deposits. Clay mantles over-lying till plains are common in the prairies.

Surface Drainage and Erosion: Little relief plus impervious soil result in low-gradient, random-patterned drainage. Gullies are located adjacent to drainage channels and exhibit softly rounded side slopes.

Soil Tones: Soil tones on the deep, extensive lake clay deposits in the prairies are very uniform. Less extensive, shallower lake deposits exhibiting greater relief, show less uniform patterns. In particular, localized highs on shallow mantles show light tonal blushes.

Gleisolic soils in the poorly drained depressions on newly fallowed fields show light tones with relatively distinct outlines. In cropped fields, the same depressions exhibit a darker tone, possibly due to retarded grain maturation. Exposure of the ash grey horizon by tillage in grey wooded soils areas results in light tones, erratically positioned throughout dark fallowed fields.

Land Use: Intensive cropping on large, level or slightly undulating fields is indicative of lake clay. Maximum land utilization is employed with the result that fields are seldom left for grazing purposes. Exceptions occur when shallow sloughs and undrained depressions preclude cropping in low-lying areas.

Air Photo Pattern - Lake Silt

Topographic Expression: Lake silt exhibits a gently undulating surface, though area-wide relief may be considered negligible.

Surface Drainage and Erosion: As in clay soils, drainage is commonly random in pattern. Gullies are located adjacent to the drainage channels and appear relatively short with medium gradients, steep side slopes and, often, flat bottoms. Soil drifting due to wind action is a reliable indicator of silts and fine sands. Seldom is the drifting reflected in the topographic expression; variations in soil tones being the sole indication of drifting.

Soil Tones: Soil tones on silt are generally drab with light-toned blushes occurring on localized high areas. An exception is the tone due to soil erosion. Drifting soil appears very light; tone boundaries are sharp, jagged and flashy. In most cases, drifting occurs on recently plowed fields and thus the light tones of the drifting soil contrast the darker tones of the more stable soil.

Many of the areas of localized soil are bounded by at least one straight side: that of an adjacent field.

Land Use: Extreme susceptibility of dry silty soils to erosion necessitates strip farming practices.

Air Photo Pattern - Lake Sand

Topographic Expression: Regional relief variations on lake sand may be considered negligible, though microrelief features are present and due to wind action. In particular, sand dunes and blow-out pits are readily identifiable and most important.

Surface Drainage and Erosion: Due to the pervious nature of the lake sands, surface drainage is at a minimum. Sand beds, overlying impervious strata and exposed by post-depositional valley erosion, often exhibit seeps and springs. The characteristic pattern is that of dark,

deep, steep-sided depressions, appearing tuber-like in plan. Seepage, appearing at the bulb-like portion of the spring, either rapidly disappears into small alluvial fans located below the spring or erodes a gully down to the valley drainage.

Soil Tones: The pattern is composed of many different elements reflecting blow-outs, stabilized zones, and drifting sand. Boundaries are distinct; blow-outs appear light, dunes and drifting sand appear very light, whereas the grassed stabilized zones are grey. Brush vegetation, found in low-lying, comparatively wet areas is darker.

Land Use: Dry areas of lake sand are generally used as grazing land. The land use element is not conclusive, but is valuable in separating lake sand areas from lake clay areas.

Examples of deep, extensive deposits of lake clay are illustrated in Fig. 23 and Fig. 24. Fig. 25 illustrates an example of shallow lake clay overlying end moraine. Examples of silt and fine sand lake plains are illustrated in Fig. 26 and Fig. 27. A sand dune belt derived from lake sand is illustrated in Fig. 28. Fig. 29 illustrates a readily identifiable example of sand dunes. A classic example of springs in a sandy stratum is illustrated in Fig. 30.

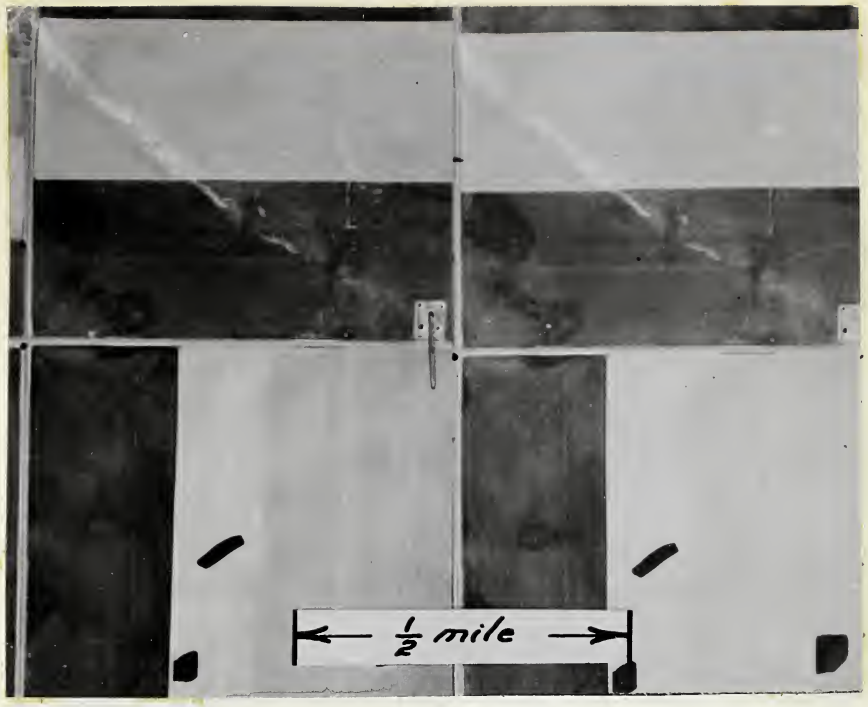


Fig. 23. T 24, R 19, W3. R.C.A.F. Photo.

This readily identifiable example of lake clay in a proglacial lake illustrates the more important features. Low relief, uniform simple tones corresponding to cropping, large fields, maximum land utilization and sharp field boundaries are the identifying elements. Note the light-toned streak denoting a ridge buried below the shallow mantle of glacial-lake clay. Such a feature may be an esker an ice-thrust ridge or an ice-crack filling.

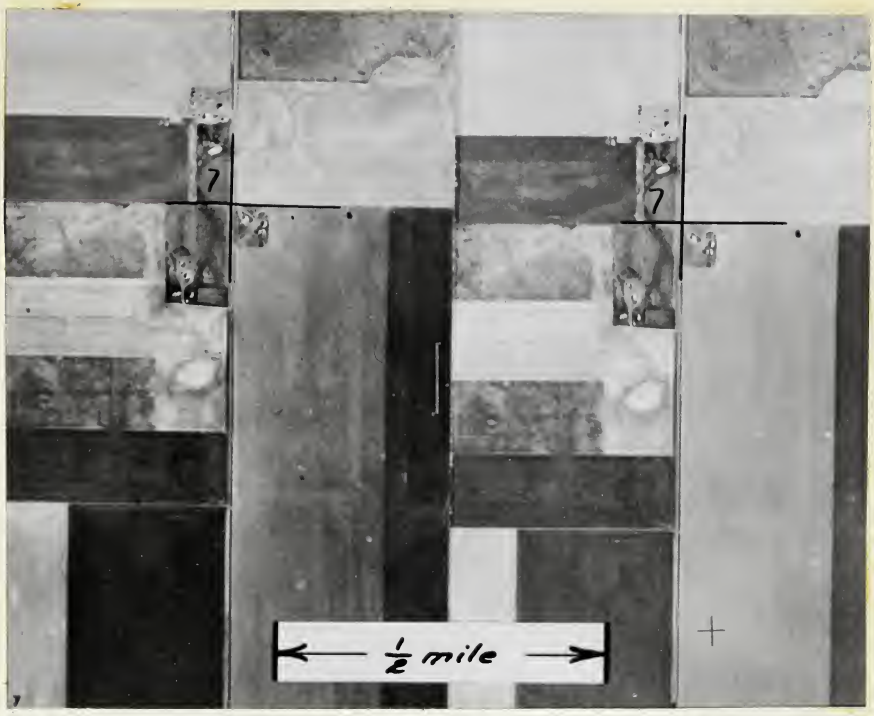


Fig. 24. T 15, R 23, W3. R.C.A.F. Photo.

The example illustrates the surface drainage and erosion elements. The drainage pattern is random; the gullies are long with low gradients and softly rounded side slopes. As is Fig. 23 maximum land utilization is practised.

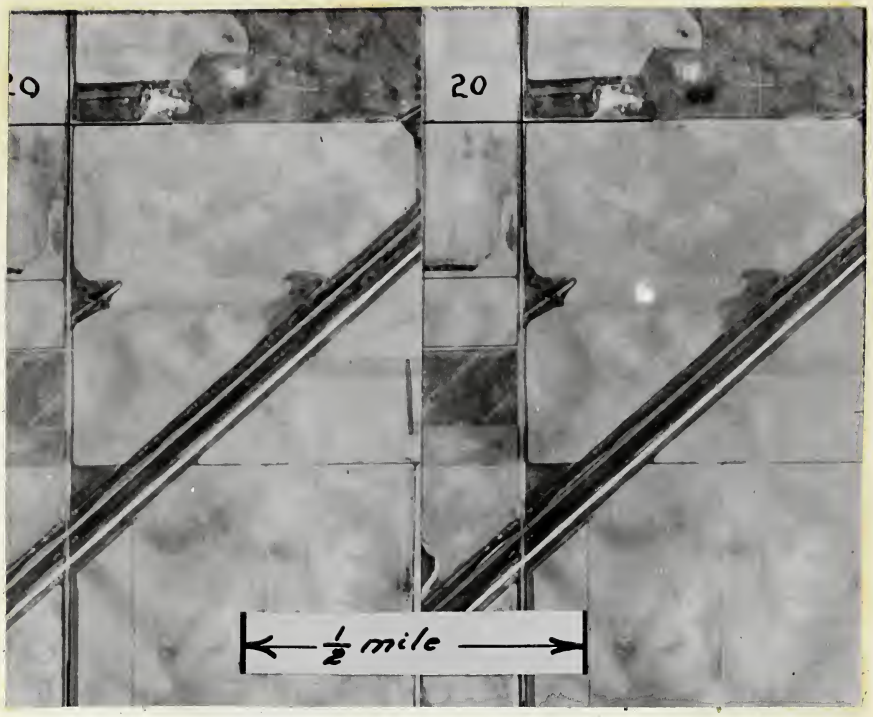


Fig. 25. T 17, R 9, W3. R.C.A.F. Photo.

A comparatively thin mantle of lacustrine clay overlies an end moraine here. Note the more or less rounded, though undulating topography. Such land forms are commonly identified by the light tone blushes on the localized high areas. To the north less subdued topography suggests a change to end moraine. Further indication of a change in land form is the change in land use.

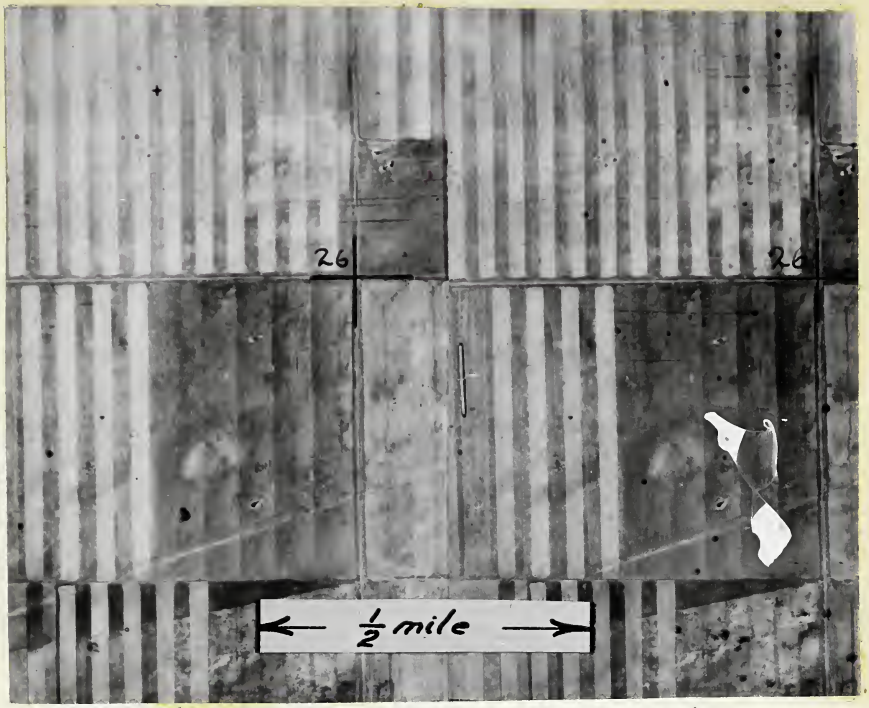


Fig. 26. T 9, R 26, W4. R.C.A.F. Photo.

Erosion preventative practises constitute conclusive evidence of the silty nature of the soil. Typical topographic expression and soil tones exist, but do not constitute conclusive evidence. Note the pipeline which is not discernible to the ground observer, but is obvious to an air photo observer.

Fig. 27. T 12, R 18, W4. R.C.A.F. Photo.

The stereopair illustrates a readily identifiable example of wind erosion on silts and fine sand. Light tones contrasted with the dark tones of the stable soil, jagged but distinct outline, and small but discernible variations in relief are the important features. Note the pattern of erosion preventative practises in the field in the northern part of the photo.

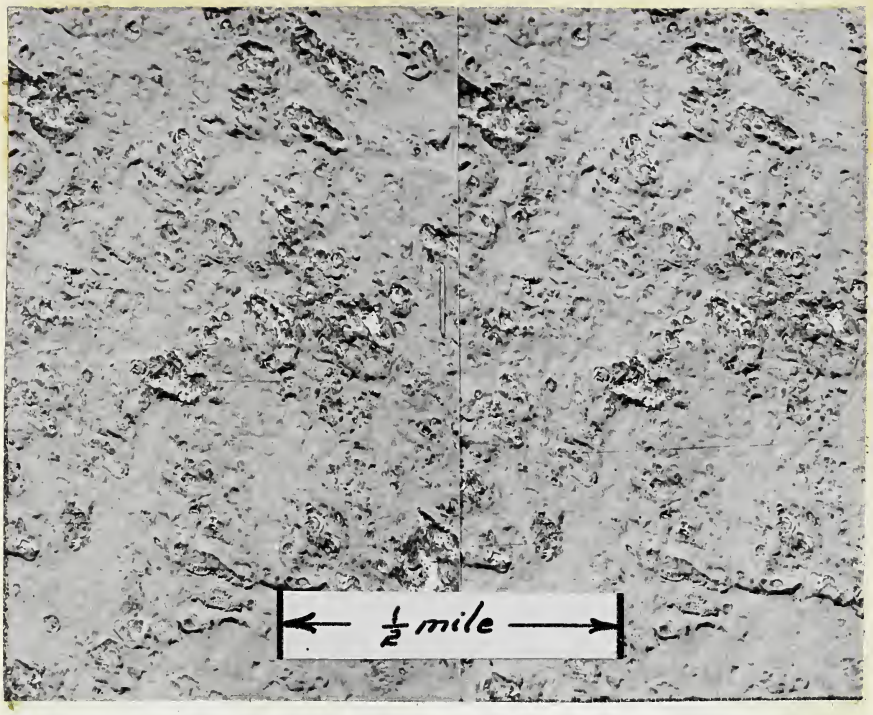


Fig. 28. T 33, R 5, W3. R.C.A.F. Photo.

Blow-out pits constitute the main identifying feature of this sand dune belt derived from lake sand. The pits, accentuated by shadow and a concentration in vegetation, are slightly elongated in the direction of the prevailing wind. Microrelief, due to the pits, exists; area-wide relief is negligible. The grain-size curves are easy to predict in areas such as this.

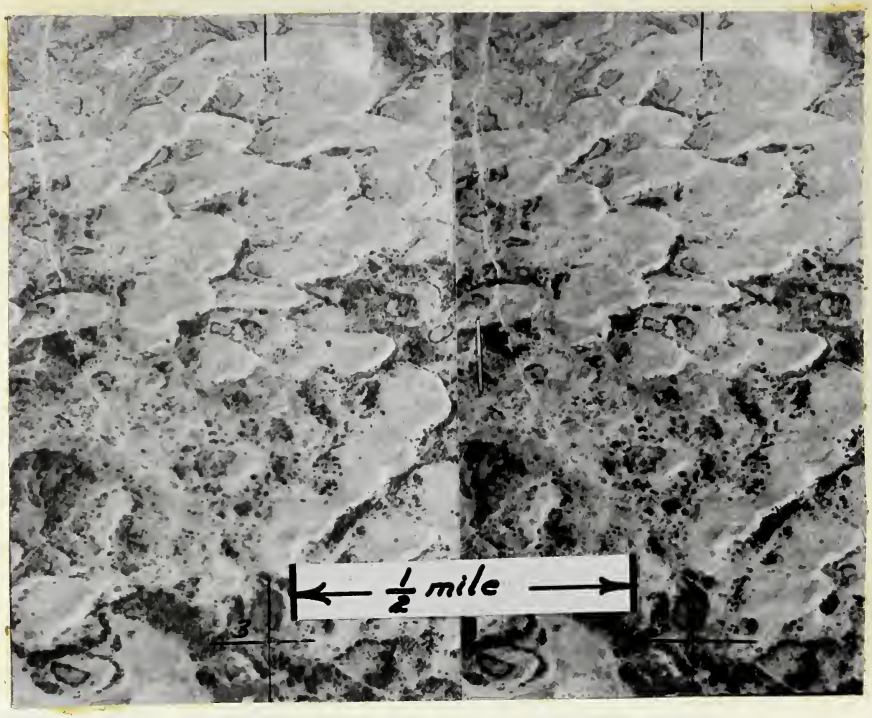


Fig. 29. T 17, R 22, W3. R.C.A.F. Photo.

The stereopair illustrates a readily identifiable example of sand dunes. Many features identify the dunes. Notable are the streamlined, parabolic shape; steep leeward slope; and shallow windward slope. The sand composing the dunes is well sorted and of medium size. It is logical to infer that the underlying material has a similar physical composition.

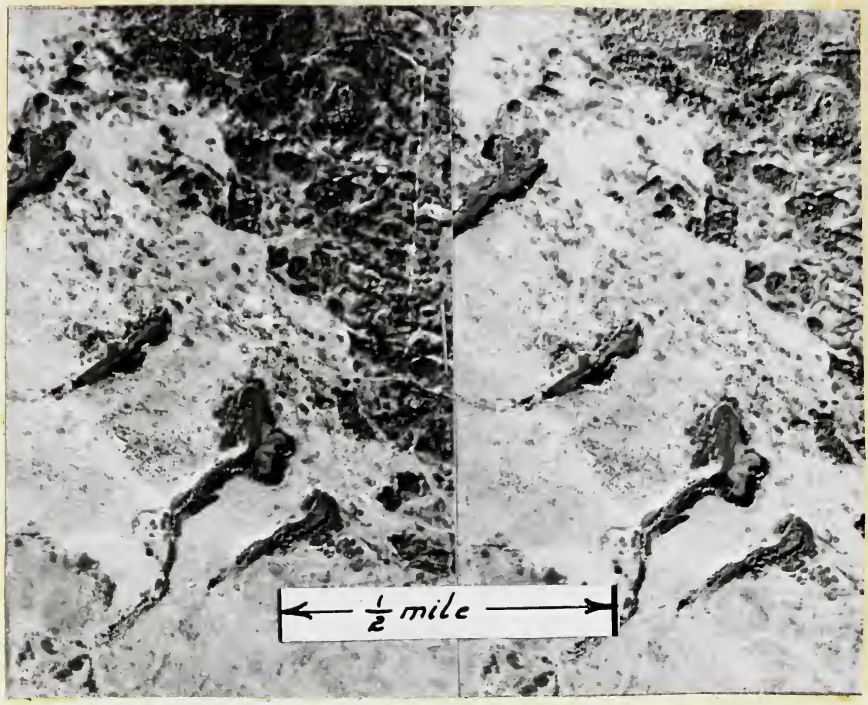


Fig. 30. T 24, R 4, W3. R.C.A.F. Photo.

A classic example of springs is illustrated in this photo. The top soil stratum is sandy and yet it may be inferred that impervious strata occur at a shallow depth. Note the blow-out pits on adjacent dunes, steep gully side-slopes, and the disappearance of the seepage into local alluvial fans -- all indicative of sandy soil.

CHAPTER III

Air Photo Analysis Applied

to

Glacial Soils in the Edmonton Area

Highway 16, West of Edmonton

(a) Test Area and Location: The larger test area consisted of approximately five hundred square miles lying within Ranges 1 to 14, Township 52, 53 and 54, West of the Fifth Meridian. The area, bordering Highway 16 between Stony Plain and Carrot Creek, west of Edmonton, was divided into four parts as follows:

Stony Plain to Kapasiwin Beach - Part I

Wabamun to Evansburgh - Part II

Evansburgh to Chip Lake - Part III

Chip Lake to Carrot Creek - Part IV

(b) Air Photos: The following air photos at a scale of two inches to-the-mile provided complete stereoscopic coverage:

A°11671 - 339 to 348

A°11714 - 137 to 150, 205 to 211.

A°11713 - 15 to 32, 39 to 51.

A°11128 - 80 to 90, 209 to 214

Mosaics at a scale of one inch-to-the-mile were constructed of each part and illustrated by the following figures:

Part I - Fig. 31

Part II - Fig. 33

Part III - Fig. 35

Part IV - Fig. 37

(c) Part I - Stony Plain to Kapasiwin Beach

During analyses both prior and after field checking reference was freely made to two reports: Glacial Geology of St. Ann Area, and Soil Survey of St. Ann Sheet.

Soil types mapped by analysis after field checking are shown in the soils map in Fig. 32. The analysis prior to field checking recognized the level outwash plain south and east of Stony Plain, but evaluated the soil texture as coarse sand and fine to coarse gravel rather than sand. The coarse granular deposits in the vicinity of Sections 8, 9, 10, 15, 16 and 17, Range 1, Township 54 were not recognized. The extensive areas located in the central portion of Part I were recognized as silt and fine sand but were thought to be a silt-rich till end moraine rather than a lacustrine silt mantle overlying a heavily pitted outwash plain. Ablation moraine west of the large crevasse filling was recognized prior to field checking. Eskers that were noted previously proved to contain the anticipated range of texture and structure. The crevasse filling was found to have a thick silt overlay which had not been previously recognized.

(d) Part II - Wabamun to Evansburgh

The analysis made after field checking is illustrated in Fig. 34. It was found to agree very closely to the analysis made prior to field checking. The boundaries between the ablation moraine in the north and the lacustrine clay mantle over the till plain were correctly located.

The existence of the kame moraine south of Isle Lake was verified. Field checking showed the material to be very poorly sorted and containing many zones and localized mantles of till and clay. Deep clay deposits west of the kame moraine postulated during the initial analysis were proven correctly mapped. The area of till overlying bedrock was originally postulated as end moraine.

(e) Part III - Evansburgh to Chip Lake

As in Part II, field checks verified the existence of the extensive deposits of deep lacustrine clay. The areas of clay overlying bedrock were not identified correctly but were postulated as end moraine areas.

(f) Part IV - Chip Lake to Carrot Creek

As mentioned in Part III, the areas of clay overlying bedrock were not recognized in the analysis prior to field checking but were postulated as end moraine areas. The remaining area to the west in Part IV was originally mapped as a thick mantle of clay overlying a till plain with local surficial coverings of sand. Field checking proved this analysis essentially correct although the clay mantle was originally postulated to be much thicker and less granular.

Namao Airport Vicinity

(a) Test Area and Location: The smaller test area consisted of eight square miles, Sections 3, 4, 9, 10, 27, 28, 33 and 34, Range 24, Township 54, West of the Fourth Meridian. The area consisted of two parts, immediately north and south of the Namao Airport.

(b) Air Photos: The analysis of the area was made with air photos A•12900 - 27 to 30, A•12915 - 428 to 431 and A•12915 - 406 to 409 which provided complete stereoscopic coverage at scale four inches-to-the-mile. A mosaic of the area was prepared and is illustrated in Fig. 40.

(c) Analysis Prior to Field Checking: Results of the analysis prior to field checking suggested a consistent mantle of highly plastic lacustrine. clay two to five feet thick occurring over a minimum of 95% of the area. This mantle appeared to cover a level to gently undulating till plain. Local areas where the clay mantle appeared to diminish in thickness were noted although no surface exposures of till were apparent. No areas indicating a significant increase in thickness of the clay mantle were observed.

Post-depositional lake erosion appeared to be responsible for the shallow, parallel northeast-trending grooves located in Section 10 of the test area and Sections 11 and 14 of the area adjoining on the east. A very thin variable mantle of poorly sorted sand and silt was thought to exist in these grooves and in other local depressions occurring throughout the area. The feathery and stringy pattern of light tones was thought indicative of this thin superficial deposit. These light tones were differentiated from those representing local highs where a thinning of the clay mantle was postulated. The light tones in this case appeared as faint

blushes with indistinct outlines, much like those exhibited in the southern half of Section 4.

In summarizing the analysis made prior to field checking, the air photo pattern suggested a uniform lacustrine clay mantle, two to five feet thick overlying a near-level till plain. This soil section was thought to exist over the greater part of the test area. Thin, erratically scattered, surface deposits of sand and silt were postulated but were thought to be of little engineering significance.

(d) Field Checks: During the subsequent one-day field check approximately twenty soil exposures -- over one-half were greater than eight feet deep -- were examined. Each one verified, with possibly some relatively minor modification, the following section:

3'-4'	Heavy, black, highly plastic lacustrine clay, no pebbles or sand lenses.
2'-3'	Massive silty clay, no pebbles or sand lenses, grading into the overlying clay.
1'-3'	Laminated silt, some clay varves, no pebbles.
1'-3'	Sandy clay and clayey sand, medium to low plasticity, high coarse sand content, coarsely varved, occasional boulders greater than seven inches in diameter, few fine and medium gravels.
1'-	Glacial till, well-graded mixture of clay, silt, sand and gravel, low plasticity, some large boulders, no varves or stratification, occasionally grading into overlying material.

Several sections on knolls showed a slight variation, i.e., diminishing in the thickness of the overlying highly plastic clay strata to approximately two feet.

The feathery and stringy pattern of light tones, was investigated and was found to be indicative of a clay gleisolic soils[1] in recently plowed depressions and poorly drained areas. No noteworthy signs of sand and silt was noted in these areas. An investigation of the light toned blushes on the knolls and highs showed a brownish clay loam, different in color to the black clay loam occuring in adjacent lower-lying areas.

(e) Conclusions: Comparison of the results of the analysis made prior to the field checking with the results of the field check indicates the following features:

(i) Analysis suggested uniform subsurface soil conditions. Field checks in approximately twenty soil exposures showed a consistent soil section.

(ii) Analysis suggested an extensive, uniform clay mantle two to five feet thick overlying till. Field checks at soil exposures showed at least two feet of clay, often between three to four feet, overlying three to six feet of soil which in turn was overlying a till-like soil.

(iii) Subtle differences exist between soil tones of recently plowed, clay gleisolic soils and erratically distributed, thin, superficial deposits of water-sorted sand. Diagnostic feature of the gleisolic soils is the fact that they invariably exist in poorly drained areas, and thus they are generally restricted to depressions.

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[1] Brown and light-grey subsoil restricted to poorly drained areas and resulting from a fluctuating ground-water level.

(iv) Uniformity of both the air photo pattern and the subsurface soil conditions preclude texture correlation; for it is not known whether the air photo pattern is indicative of the overlying, highly plastic clay mantle, or indicative of the general soil section extending down to the till.

Discussion

The following statements are based on the result of the air photo analysis applied to the two test areas in the Edmonton Area.

(a) Airphoto patterns of certain soil textures and structures appeared to be consistent with those recognized elsewhere by the author and thus were readily recognized in the test areas. In particular, the silt and fine sand on high, droughty areas had the characteristic erosion pattern. Certain elements in the air photo pattern of deep clays and clay mantles overlying both till plains and end moraines were consistent with those throughout Western Canada. Eskers, crevasse fillings, sand dunes, muskegs and slumps were readily identified by their universal pattern in Western Canada.

(b) Photo patterns hitherto unknown by the author were encountered on lake clay areas. The intricate pattern of light tones exhibited by gleisolic clay and by clay located in the grey wooded soil zones were mistaken for erratic superficial deposits of poorly sorted silt and sand.

(c) Forested bedrock areas had seldom been previously encountered in air photo analysis by the author. Correlations between air photo patterns and the local bedrock suggested that topographic expression and vegetation were the sole reliable identifying elements. Significant drainage and erosion elements could not be recognized.

(d) Air photo analysis in conjunction with a limited amount of field checking appeared to be an expedient and relatively accurate method of mapping and identifying of soils in the large scale and small scale test areas. Differences in the amount of detail that can be obtained from photos of various scales was readily apparent. In regards to the Namao

Airport area where air photo coverage at four-inches-to-the-mile was available it was suggested that minor differences could have been readily detected if they had existed. Unfortunately field checking showed the subsurface soil conditions to be relatively uniform.

Larger scale photos of the area west of Edmonton precluded mapping of the soil types to the same degree of detail as that of the Namao Airport area. Part I of the Area West of Edmonton was mapped to a slightly greater detail than that of other areas to the west. This was primarily due to personal academic interest in a local soil texture and mode of deposition.

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APPENDIX I

Stereovision

Two adjacent air photos or stereopairs are arranged along their flight line, and placed such that identical land surface points are approximately two inches apart. A stereoscope is centered over the two points, and with relaxed vision through the instrument, the two photos are moved slightly apart or together until the images of any two identical surface points coincide. A rectangular area showing topography in relief will be seen, and can be displaced to one side by turning back the inside edge of the overlapping photo.

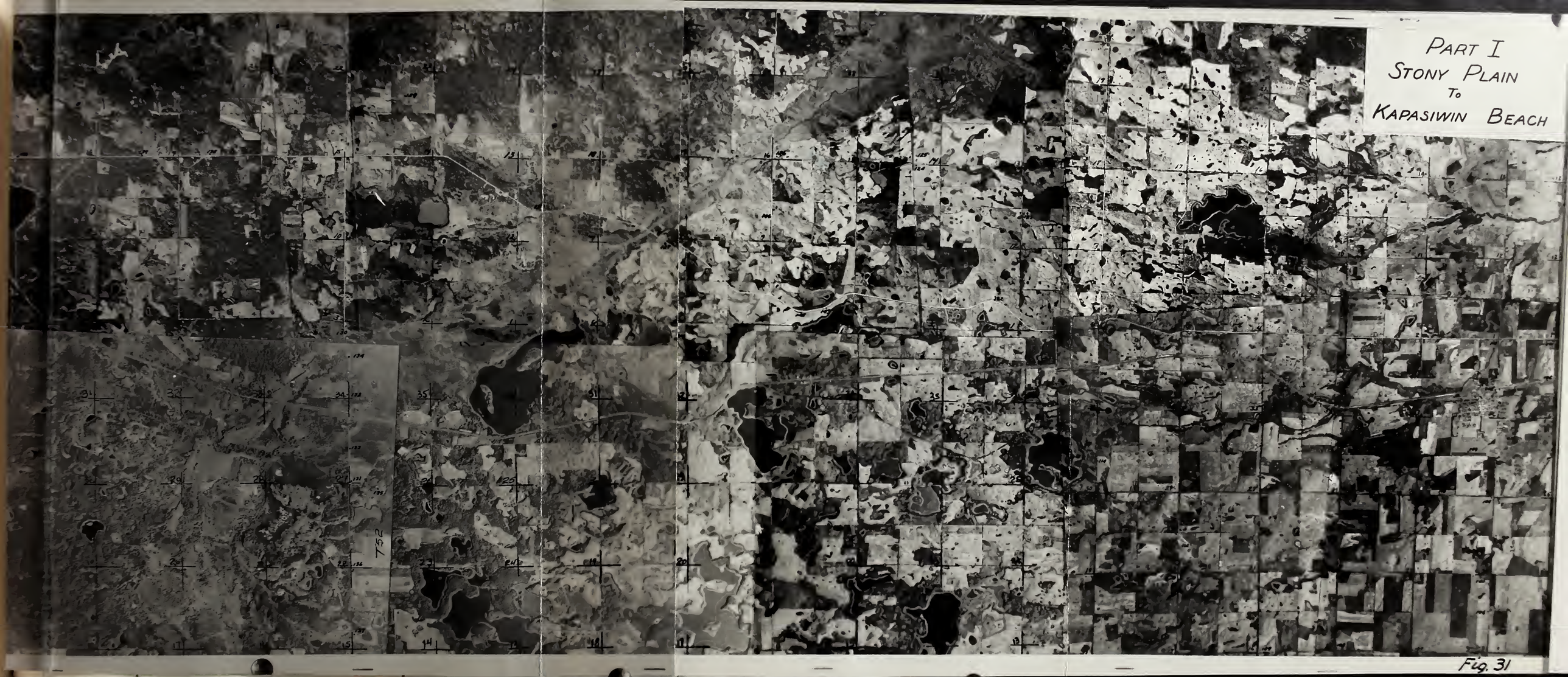


Fig. 31

LEGEND

Uniform, fine to medium sand with some silt and fine gravel. Level to undulating topography. (Unpitted outwash plain)

Stratified, uniform silt to fine sand overlain by mantle* of clayey silt. Occasional lenses of coarse sand to fine gravel. Rolling to hilly topography. (Heavily pitted outwash) A few hills show materials resorted and deposited by wind.

Poorly sorted sand and gravel overlain by a mantle* of clayey silt. Rolling to hilly topography. (Heavily pitted gravelly outwash plain or kame moraine)

Finely-stratified uniform silt overlain by a thick mantle* of stratified clayey silt. Undulating to rolling topography. (Heavily pitted outwash plain overlain by lacustrine clayey silt and silt)

Deep, stratified silt and clayey silt. Occasional clay varve. Rolling to hilly topography. (Lacustrine silt over end moraine)

Well-graded, massive mixture of clay, silt, sand and gravel (till) overlain by variable mantle* of poorly sorted sandy clays and clayey sands. Undulating to rolling topography. (Abation moraine)

Well-graded, massive mixture of clay, silt, sand and gravel (till) overlain by mantle* of plastic clay. Undulating to rolling topography. (Lacustrine clay over till plain)

MISCELLANEOUS SOILS

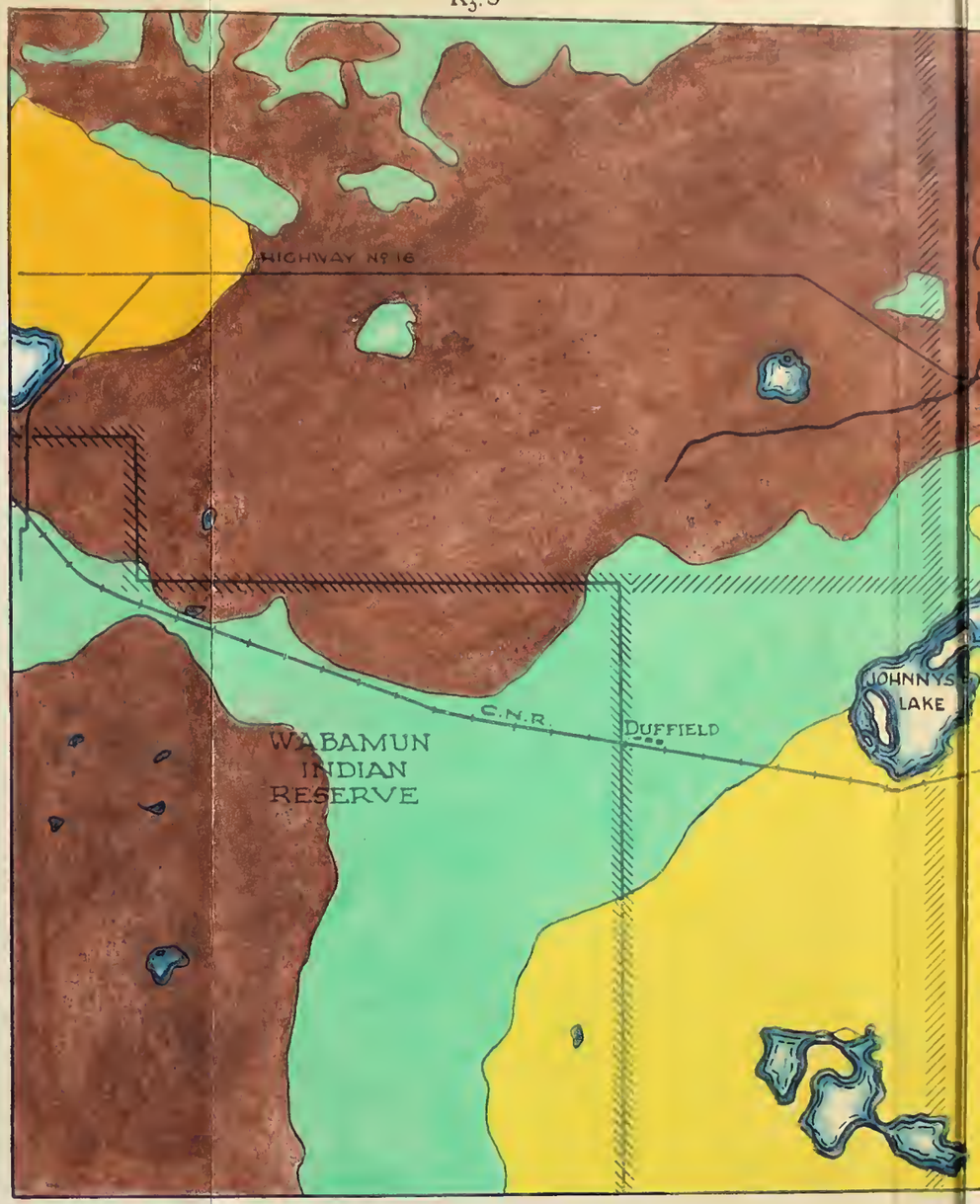
Uniform, fine to medium sand. (Sand dunes)

Uniform silt and clayey silt. (Buried crevasse filling)

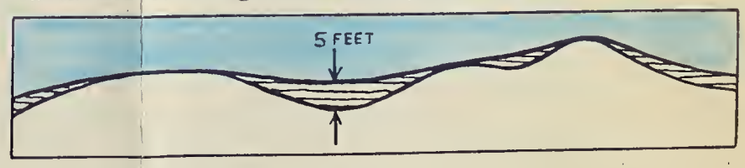
Poorly sorted, erratically stratified sand and gravel. (Eskers)

Muskeg and highly organic soils.

Rg. 3



* Mantle refers to the uppermost soil stratum, 0 to 5 feet thick and covering at least 80% of an area.



Rg.2

Rg.1

Tp.53

Tp.52

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF ALBERTA

ENGINEERING·SOILS·MAP

PART I.

STONY PLAIN TO CARROT CREEK,
HIGHWAY NO.16 WEST OF EDMONTON, ALBERTA.

STONY PLAIN TO KAPASIWIN BEACH

PREPARED FROM AERIAL PHOTOGRAPHS BY D. H. POLLOCK
SCALE: 1 INCH = 1 MILE. AUGUST 1955.

FIG.32

Fig. 33

LEGEND

Poorly sorted sand and gravel overlain by mantle* of clay. Rolling to hilly topography. (Kames and kame moraine overlain by lacustrine clay bed)

Deep mantle* of well-graded, massive mixture of clay, silt, d gravel (till) overlying weathered sandstone bed- . Rolling to hilly topography. (Till and moraine ng bedrock)

ghly plastic clay. Level to undulating topography. ine clay bed)

Well-graded, massive mixture of clay, silt, sand and gravel (till) overlain by variable mantle* of poorly sorted sandy clays and clayey sands. Undulating to rolling topography. (Abation moraine)

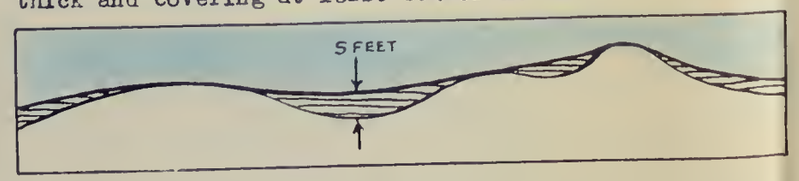
Well-graded, massive mixture of clay, silt, sand and gravel (till) overlain by mantle* of plastic clay. (Undulating to rolling topography. (Lacustrine clay over till plain)

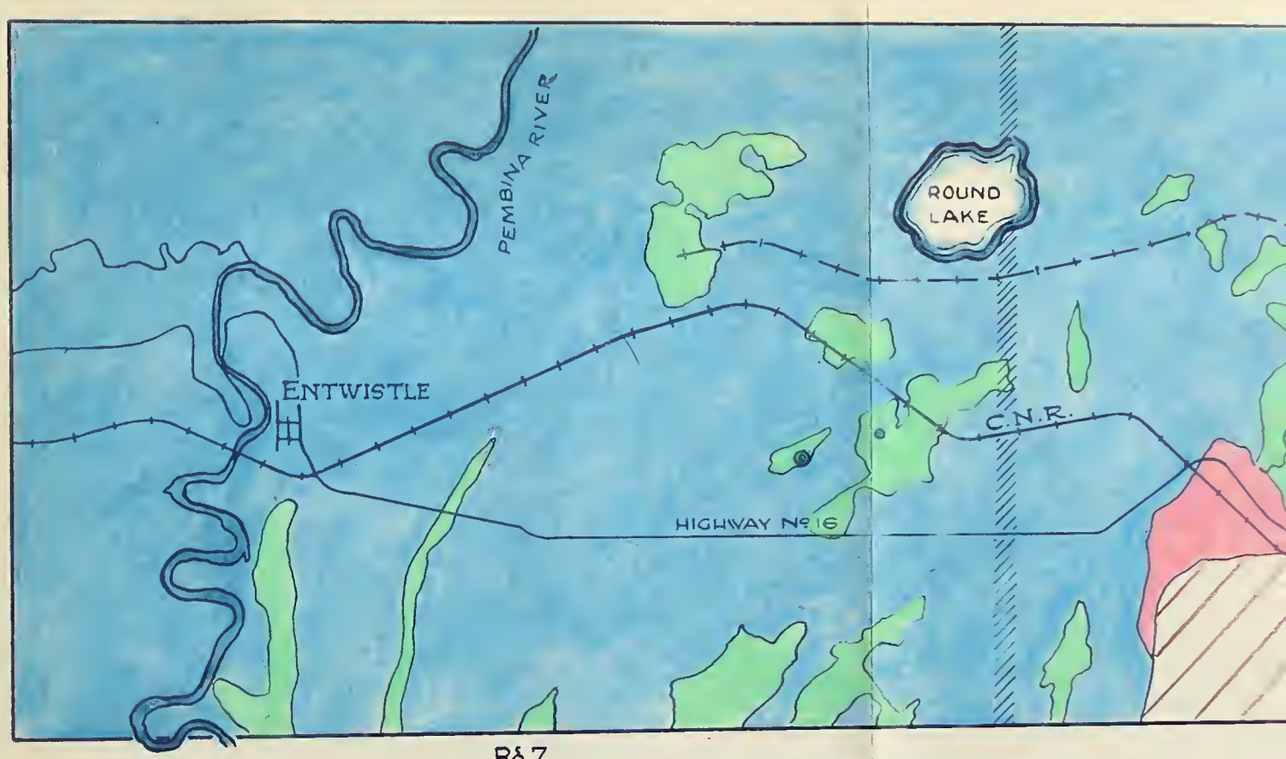
Poorly sorted, erratically stratified sand and gravel. (Eskers)

Muskeg and highly organic soils.

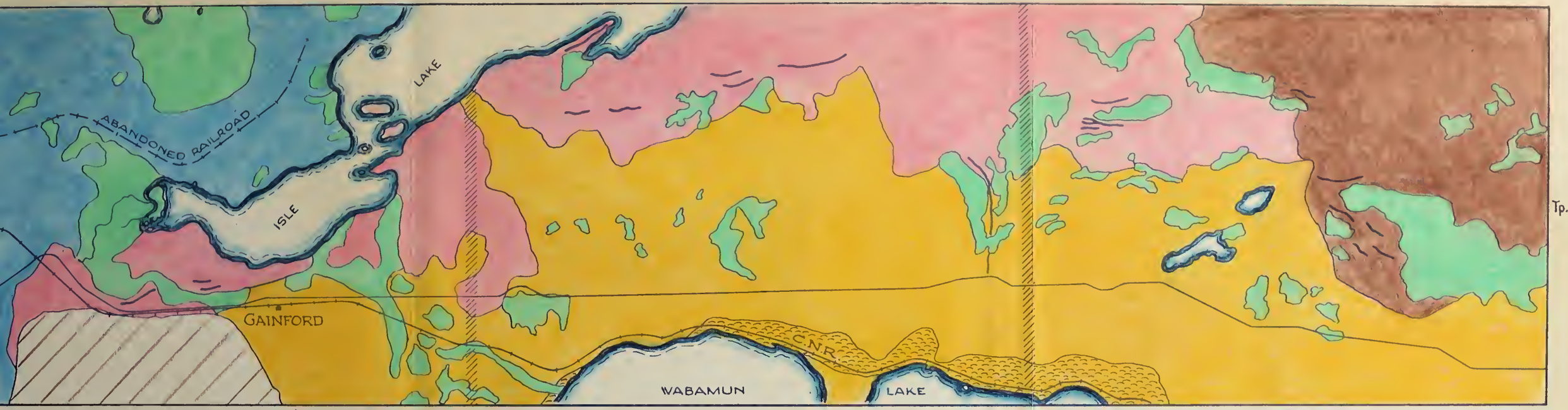
Mantle of soft, disturbed cohesive soil overlying disturbed bedrock. Hilly topography. (Slump)

* Mantle refers to the uppermost soil stratum, 0 to 5 feet thick and covering at least 80% of an area.





Rg.7



Tp.53

R.6 R.5 R.4

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF ALBERTA

ENGINEERING·SOILS·MAP

PART II

STONY PLAIN TO CARROT CREEK,
HIGHWAY NO.16 WEST OF EDMONTON, ALBERTA.

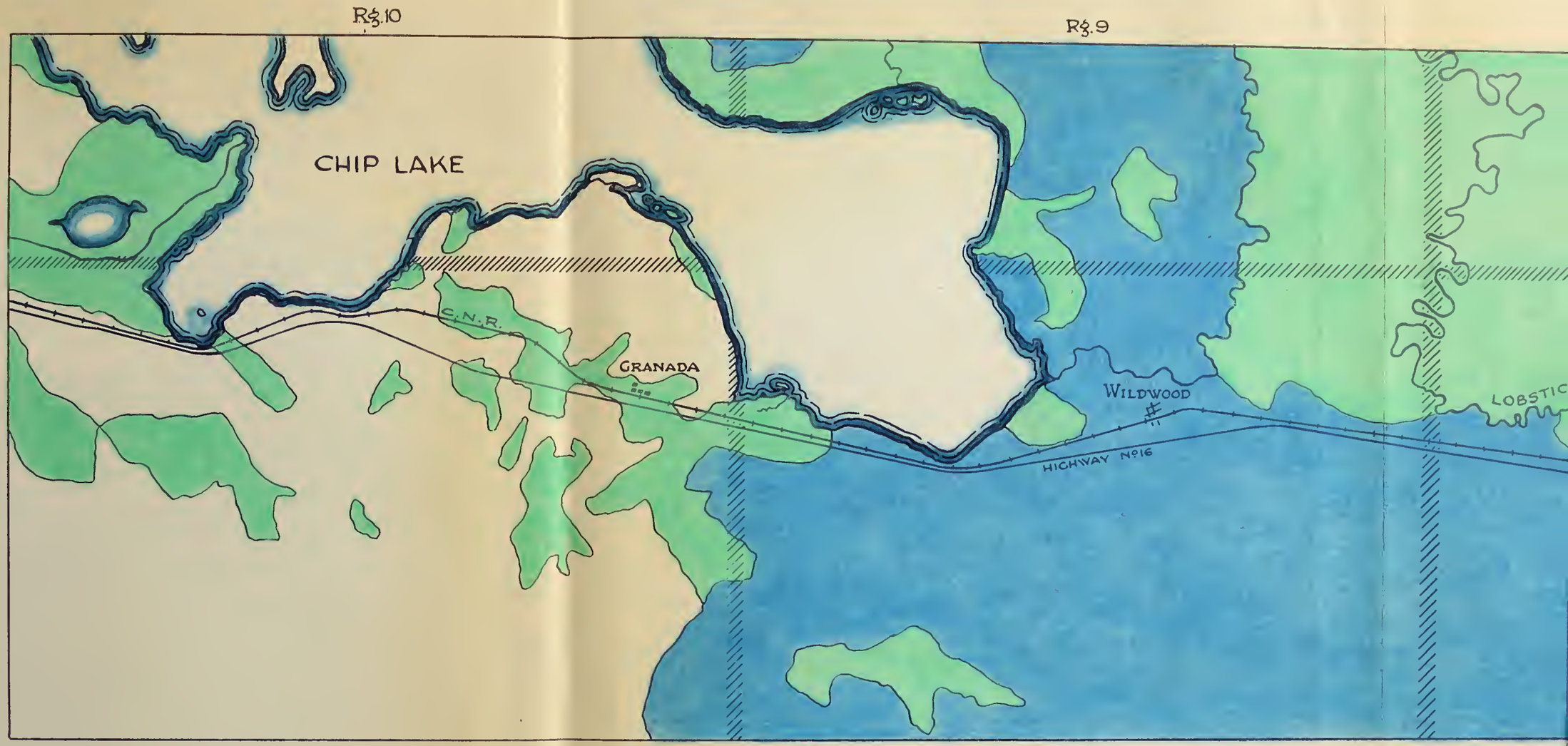
WABAMUN TO EVANSBURGH

PREPARED FROM AERIAL PHOTOGRAPHS BY D. H. POLLOCK
SCALE: 1 INCH = 1 MILE AUGUST 1955.

FIG.34

PART III
EVANSBURGH
TO
CHIP LAKE

Fig. 35



LEGEND

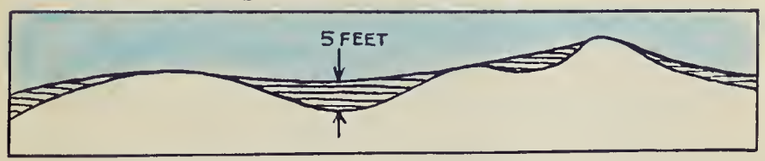
Soft, weathered sandstone bedrock overlain by mantle* of clay. Rolling to hilly topography. (Sandstone bedrock overlain by lacustrine clay bed)

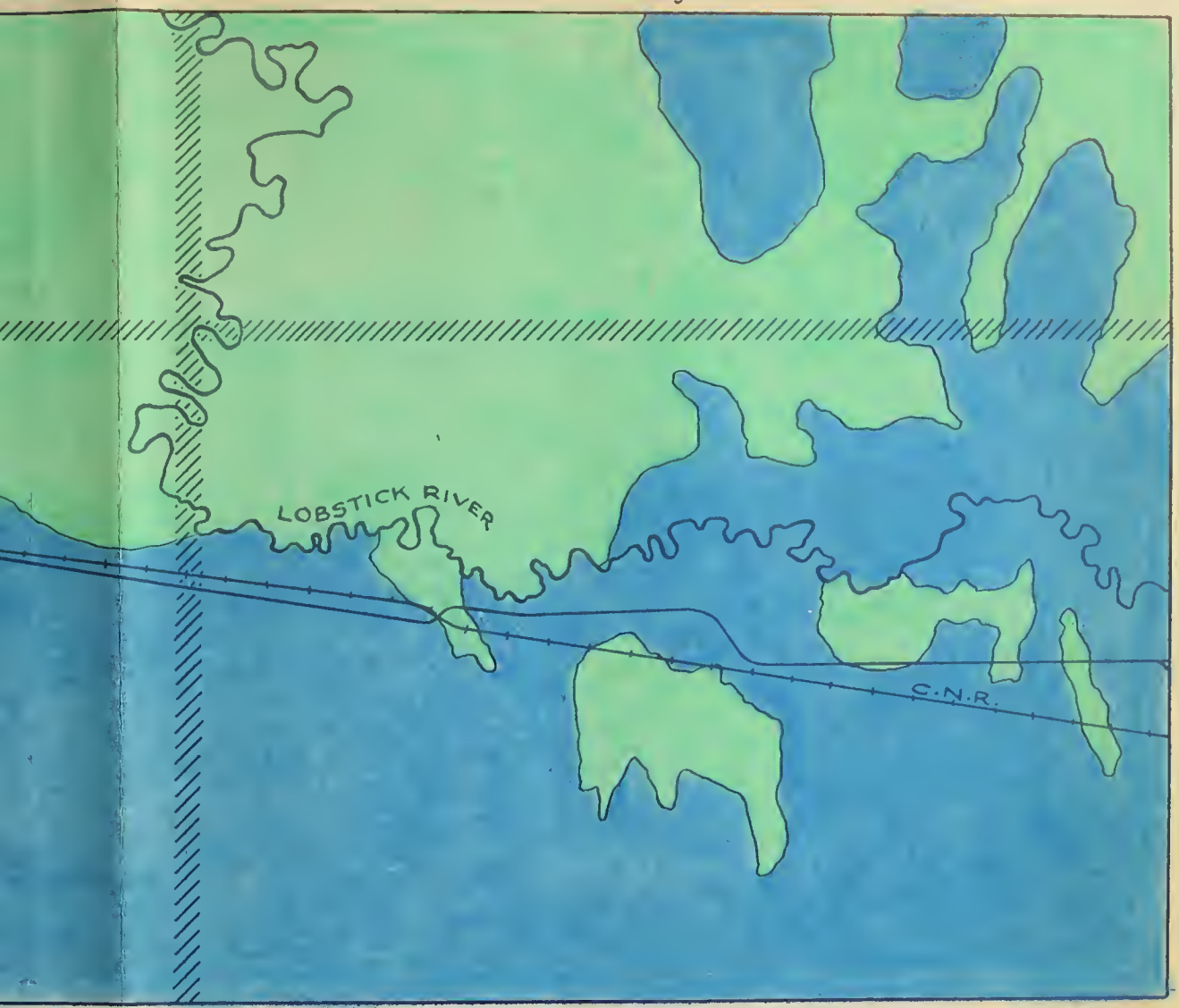
Deep, highly plastic clay. Level to undulating topography. (Lacustrine clay bed)

MISCELLANEOUS SOILS

Muskeg and highly organic soils.

* Mantle refers to the uppermost soil stratum, 0 to 5 feet thick and covering at least 80% of an area.





DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF ALBERTA

ENGINEERING·SOILS·MAP

PART III

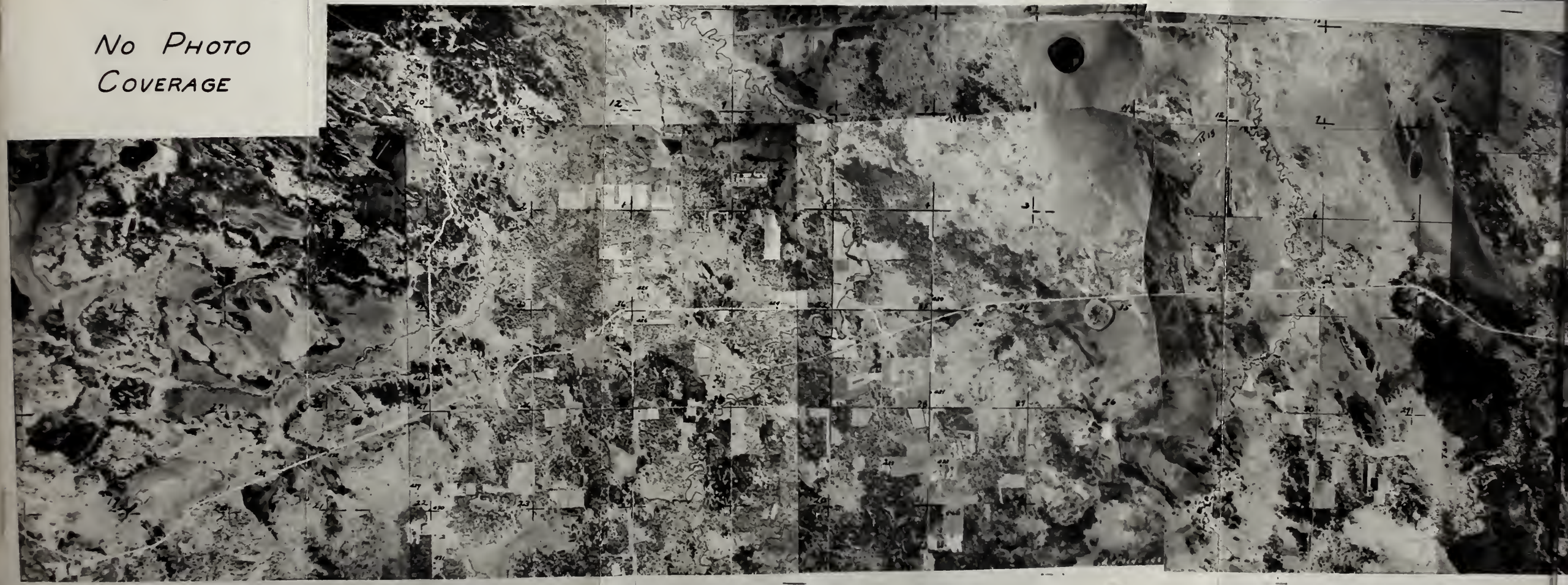
STONY PLAIN TO CARROT CREEK,
HIGHWAY NO.16 WEST OF EDMONTON, ALBERTA.

EVANSBURGH TO CHIP LAKE

PREPARED FROM AERIAL PHOTOGRAPHS BY D. H. POLLOCK
SCALE: 1 INCH = 1 MILE. AUGUST 1955.

FIG. 36

No Photo Coverage



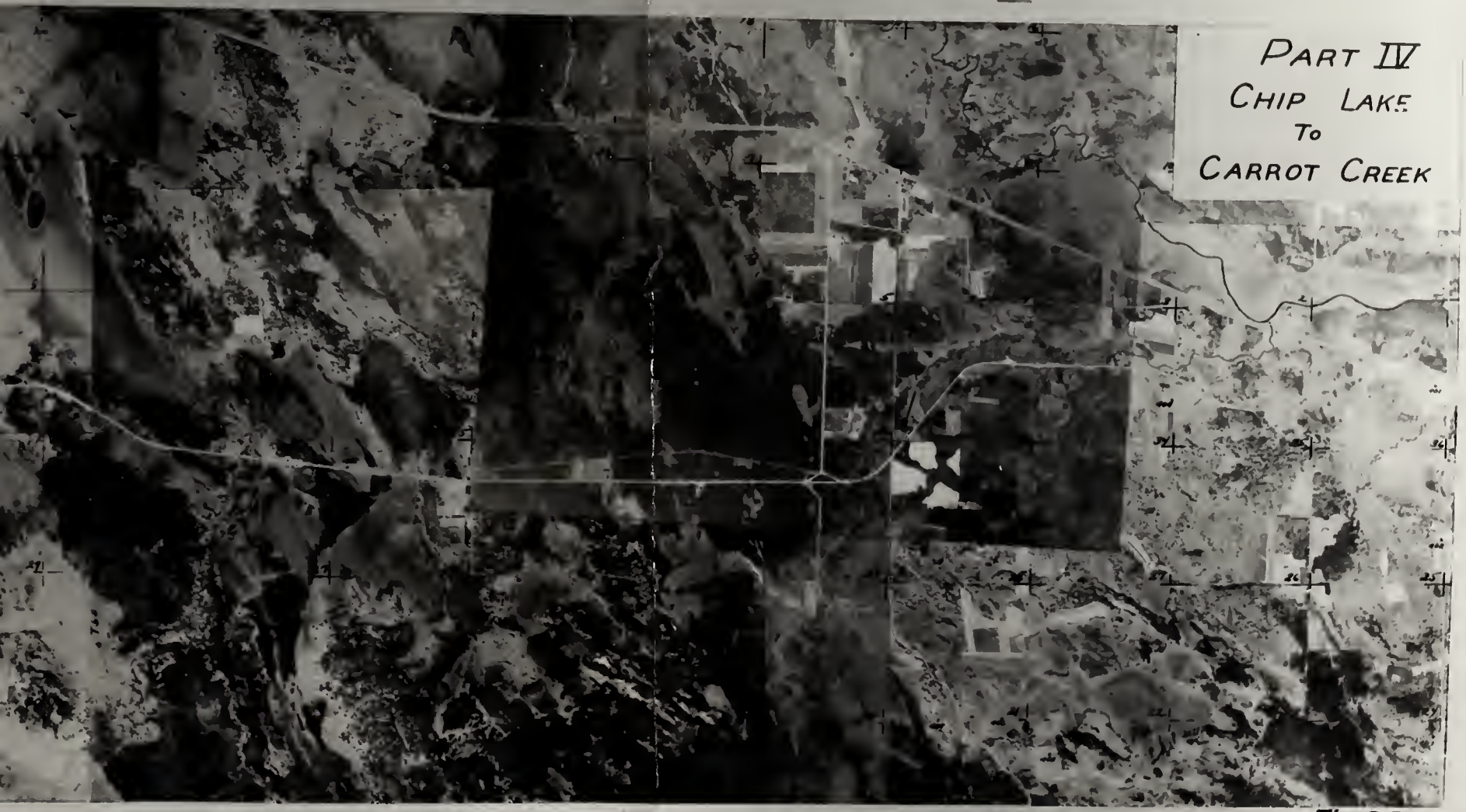
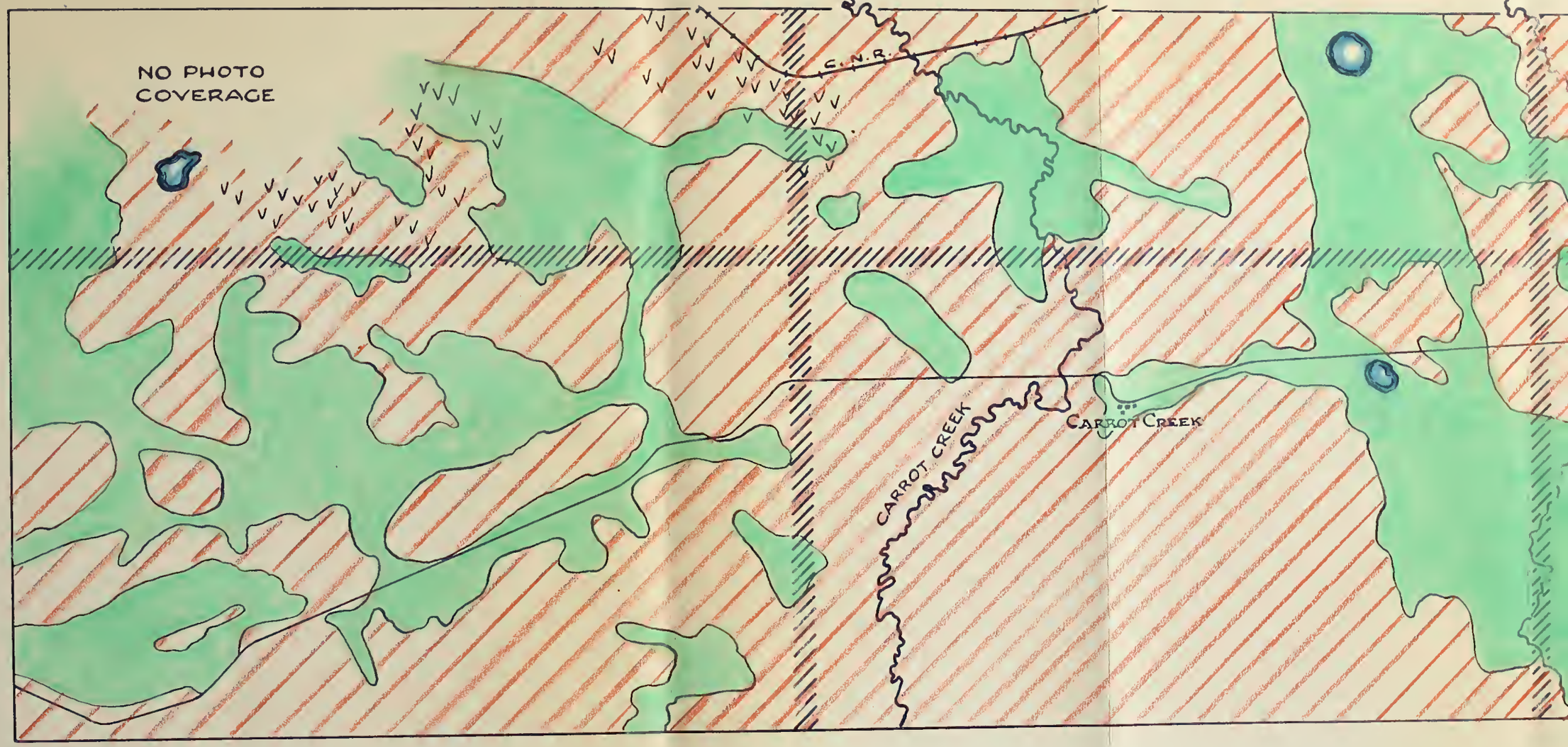


Fig. 37

Rg. 14

Rg. 13



LEGEND

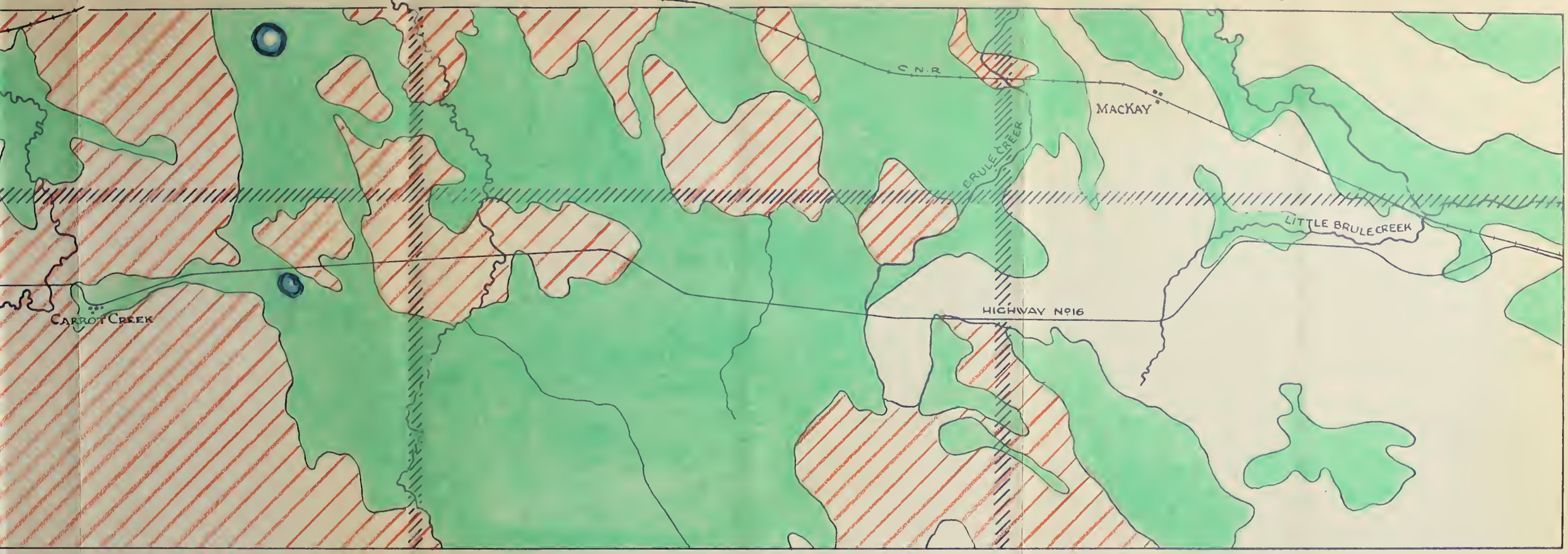
Well-graded, massive mixture of clay, silt sand and gravel (till) overlain by mantle * of varved, pebbly clay. In part beached and washed (sandy phase) Level to undulating topography. (Lacustrine clay over till plain)

Soft, weathered sandstone bedrock overlain by a mantle* of clay. Rolling to hilly topography. (Sandstone bedrock overlain by lacustrine clay bed)

MISCELLANEOUS SOILS

Uniform, fine to medium sand. (Sand dunes)

Muskeg and highly organic soils.



MISCELLANEOUS SOILS

Uniform, fine to medium sand. (Sand dunes)

Muskeg and highly organic soils.

* Mantle refers to the uppermost soil stratum, 0 to 5 feet thick and covering at least 80% of an area.

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF ALBERTA

ENGINEERING·SOILS·MAP

PART IV

STONY PLAIN TO CARROT CREEK,
HIGHWAY NO.16 WEST OF EDMONTON, ALBERTA.

CHIP LAKE TO CARROT CREEK

PREPARED FROM AERIAL PHOTOGRAPHS BY D. H. POLLOCK
SCALE: 1 INCH = 1 MILE. AUGUST 1955.

FIG. 38

RESEARCH COUNCIL OF ALBERTA, MAP 24, REPORT 67, 1954

PRELIMINARY MAP
GLACIAL GEOLOGY

ST. ANN AREA

PROVINCE OF ALBERTA
WEST OF FIFTH MERIDIAN
Scale 4 Miles to 1 Inch

LEGEND

CENOZOIC

QUATERNARY
RECENT
FLUVIAL MATERIALS
- 101 — Muck and swamp
- Gravel
- 202 — Sand and gravel

AEOLIAN MATERIAL
- 200 — Sand dunes

LACUSTRINE AND BEACH MATERIALS
- 201 — Beach sand and silt
- 202 — Sand and gravel
- 203 — Reworked sandstone

PLEISTOCENE
GLACIAL MATERIAL
- 300 — Moraine-silt till in part bedded

GLACIO-LACUSTRINE MATERIALS
- 400 — Lacustrine clay in part pre-silt till
- 401 — Clay, modified, high relief
- 402 — Interglacial sand
- 500 — Modified brown till, ground moraine beached and washed till

GLACIAL MATERIAL
- 600 — Ground moraine, massive brown till

TERTIARY
PALEOCENE
PASKAPOO FORMATION
- 701 — Sandstone

MESOZOIC
UPPER CRETACEOUS
EDMONTON FORMATION
- 702 — Sandstone, bentonite shale and coal seams

Saskatchewan gravel
Superposition of material in contact
Coal mines

Geology by G. A. Collins and A. G. Swan

Main highways
Post office and railway stations
Marsh and muskeg
Height in feet above mean sea-level
Approximate magnetic declination 24° 30' East, 1950.

Cartography taken from Sectional Sheet 314, 1933.

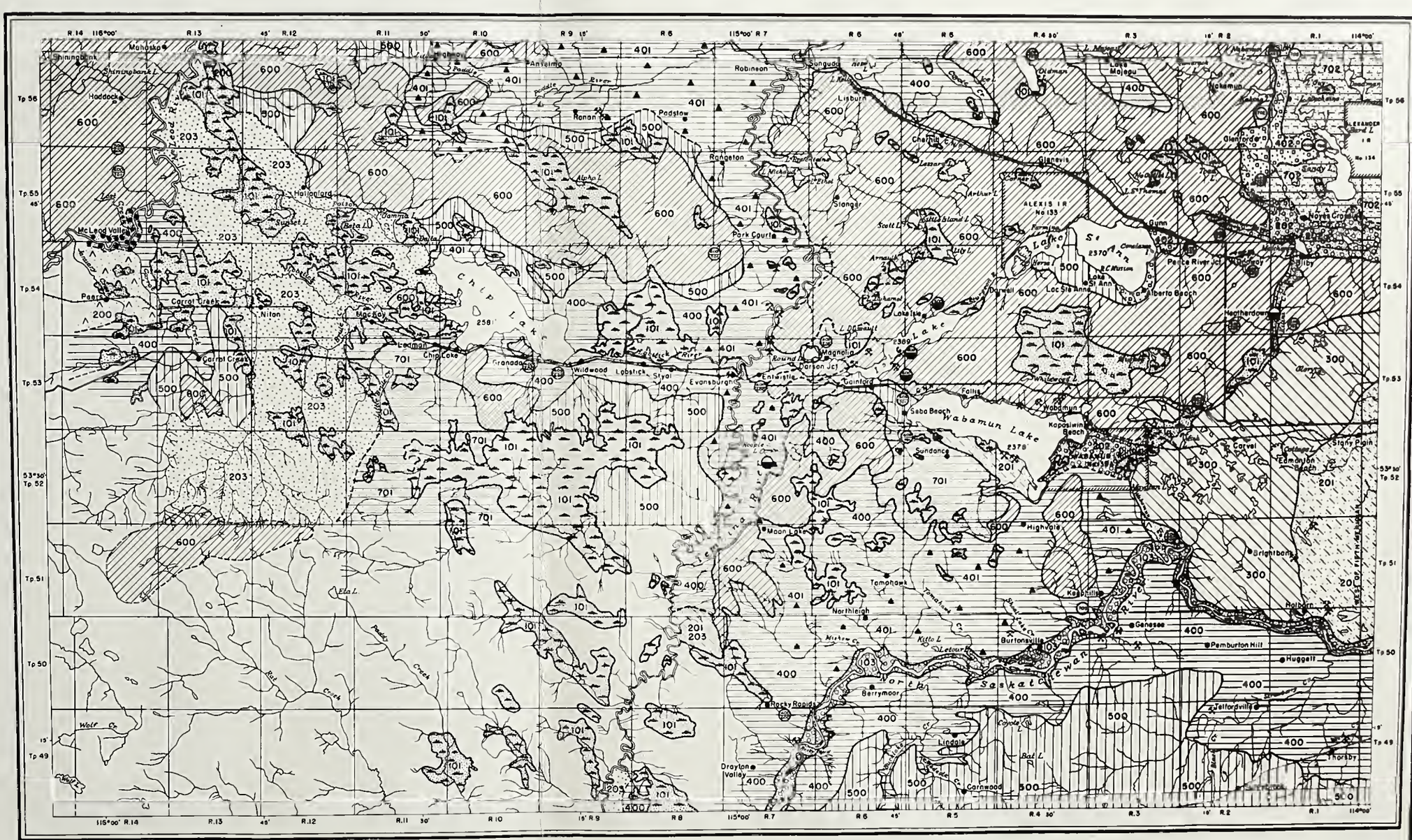


Fig. 39

Fig 40